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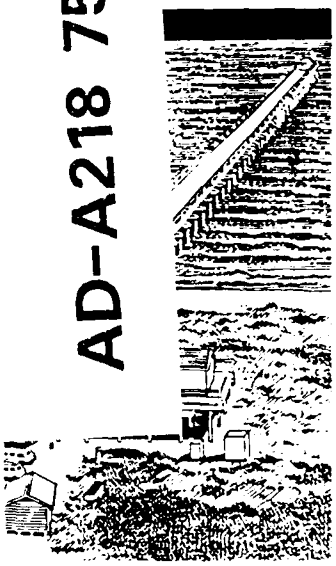

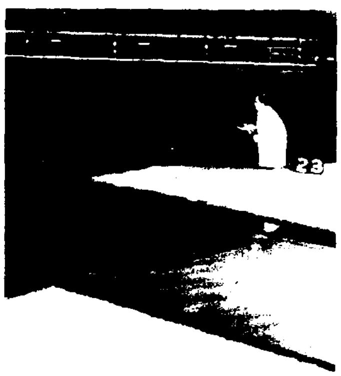

TECHNICAL REPORT CERC-89-13

WAVE CONDITIONS FOR PROPOSED HARBOR DEVELOPMENT IN LOS ANGELES OUTER HARBOR, LOS ANGELES, CALIFORNIA

Coastal Model Investigation

by

Robert R. Bottin, Jr., Larry R. Tolliver

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DEPARTMENT OF THE ARMY
Waterways Experiment Station, Corps of Engineers
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A 1:100-scale (undistorted) hydraulic model of Los Angeles Outer Harbor, California, was used to investigate short-period storm wave conditions for proposed harbor development located near the Angel's Gate entrance. The model reproduced the proposed harbor expansion, Angel's Gate entrance, portions of the existing breakwaters, and sufficient bathymetry in San Pedro Bay to permit generation of the required test waves. An 80-ft-long electro-hydraulic, unidirectional spectral wave generator and an automated data acquisition and control system were utilized in model operation. It was concluded from the model investigation that:

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18. SUBJECT TERMS (Continued).

Breakwaters	Los Angeles and Long Beach Harbors, California
Harbors, California	Short-period storm waves
Hydraulic models	Wave protection

19. ABSTRACT (Continued).

a. The originally proposed outer harbor expansion plan (Plan 1) will result in wave heights that will exceed the established criteria of 6.0 ft in the tanker terminal and 1.5 ft in the container terminal a small percentage of the time. Maximum wave heights obtained were greater than 10 and 4 ft in the tanker and container terminals, respectively. The criterion will be exceeded on an average of 7.35 hours per year in the tanker terminal and 21.45 hours per year in the container terminal.

b. Sealing of the Middle Breakwater (Plan 5) will result in slightly improved wave conditions in the container terminal of the outer slip for test waves from 209 and 154 deg.

c. A 200-ft westerly extension of the Middle Breakwater (used for several test plans) will slightly, but not significantly, reduce wave heights in vessel terminal areas.

d. Decreasing the navigation width between the proposed landfill and Middle Breakwater from 1,200 to 1,000 ft (Plan 8) will not significantly reduce wave heights at the terminals; however, an increase of the navigation opening to 1,400 ft (Plan 22) will substantially increase wave conditions in these areas.

e. The 1,800-ft-long San Pedro Breakwater spur in conjunction with a 200-ft westerly extension of the Middle Breakwater (Plan 14) will result in wave heights that exceed the established criterion in the container terminal and that meet the criterion in the tanker terminal areas. Maximum wave heights obtained in the container terminal were about 3 ft, but the criterion at this location will be exceeded on an average of only about 4.65 hours per year.

f. The installation of vertical walls in the southern slip (Plan 19) will result in very rough and confused wave conditions in the container terminal due to wave reflections with wave heights up to 9 ft at this location.

g. Reducing the southern slip width from 1,000 to 800 ft (Plan 20) will result in wave heights that exceed the established criterion in the container and tanker terminals; however, wave heights were of less magnitude than the original Plan 1 expansion configuration and the criteria would be exceeded a smaller percentage of the time. Maximum wave heights were 8.2 and 2.6 ft in the tanker and container terminals, respectively. It is estimated the established 1.5-ft criterion in the container terminal would be exceeded on an average of 3.45 hours per year, and the 6.0-ft criterion in the tanker terminal exceeded about 4.2 hours per year.

h. The revetted/vertical wall northern slip configuration (Plan 24) will result in the established 1.5-ft wave-height criterion being exceeded by only 0.2 ft at one mooring location for only one wave condition. This condition will occur on an average of only 0.15 hour per year.

PREFACE

This report presents the results of a physical model study of Los Angeles Outer Harbor, with respect to short-period storm wave conditions, for proposed harbor development located near the Angel's Gate entrance. A request for the model investigation was initiated by the Port of Los Angeles in coordination with the US Army Engineer District (USAED), Los Angeles. Authorization for the US Army Engineer Waterways Experiment Station (WES) to perform the study was subsequently granted by Headquarters, US Army Corps of Engineers. Funds were provided by the Port of Los Angeles and authorized by USAED, Los Angeles, on 1 March 1988 and 21 December 1988.

The model study was conducted during the period from June 1988 to April 1989 by personnel of the Wave Processes Branch (WPB), Wave Dynamics Division (WDD), Coastal Engineering Research Center (CERC), under the direction of Dr. J. R. Houston, Chief of CERC; Mr. C. C. Calhoun, Jr., Assistant Chief of CERC; Mr. C. E. Chatham, Jr., Chief of WDD; and Mr. D. G. Outlaw, Chief of WPB. The tests were conducted by Messrs. M. G. Mize and Larry R. Tolliver, Civil Engineering Technicians, Mr. D. M. Bell-Winston, Contract Student, and Mr. W. M. Henderson, Computer Technician, under the supervision of Mr. R. R. Bottin, Jr., Project Manager. Testing requirements and acceptable operational wave criteria were provided by Mr. John Warwar, 2020 Program Director of the Port of Los Angeles. This report was prepared by Messrs. Bottin and Tolliver.

During the course of the investigation, liaison was maintained by means of conferences, telephone communications, and monthly progress reports.

The following personnel visited WES to observe model operation and/or participate in conferences during the course of the study:

Alan Alcorn	USAED, Los Angeles
Angel Fuertes	USAED, Los Angeles
Peter Neilans	USAED, Los Angeles
Bob Rados	Port Commissioner, Port of Los Angeles
Floyd Clay	Port Commissioner, Port of Los Angeles
Bruce Seaton	Const. Mgmt. Group, Port of Los Angeles
Vern Hall	Chief Harbor Engineer, Port of Los Angeles
John Warwar	2020 Program Director, Port of Los Angeles
Lisa Sales	Port of Los Angeles

COL Larry B. Fulton, EN, is Commander and Director of WES. Dr. Robert W. Whalin is Technical Director.

CONTENTS

CONVERSION FACTORS, NON-SI TO SI (METRIC)
UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
acres	4046.856	square metres
feet	0.3048	metres
knots	1.8532	kilometres per hour
miles (US statute)	1.609344	kilometres
square feet	0.09290304	square metres
square miles (US statute)	2.589988	square kilometres

WAVE CONDITIONS FOR PROPOSED HARBOR DEVELOPMENT IN LOS ANGELES OUTER HARBOR, LOS ANGELES, CALIFORNIA

Coastal Model Investigation

PART I: INTRODUCTION

Background

1. The ports of Los Angeles and Long Beach are located in San Pedro Bay along the southern coast of California (Figure 1). They have, historically, experienced long-period surge activity which occasionally results in mooring difficulties for ships berthed in various locations within the harbors' complex. In coordination with the US Army Corps of Engineers (Corps), the Ports of Los Angeles and Long Beach are conducting studies for harbor development and expansion to accommodate future needs. Descriptions of the existing breakwaters may be found in Bottin (1988).

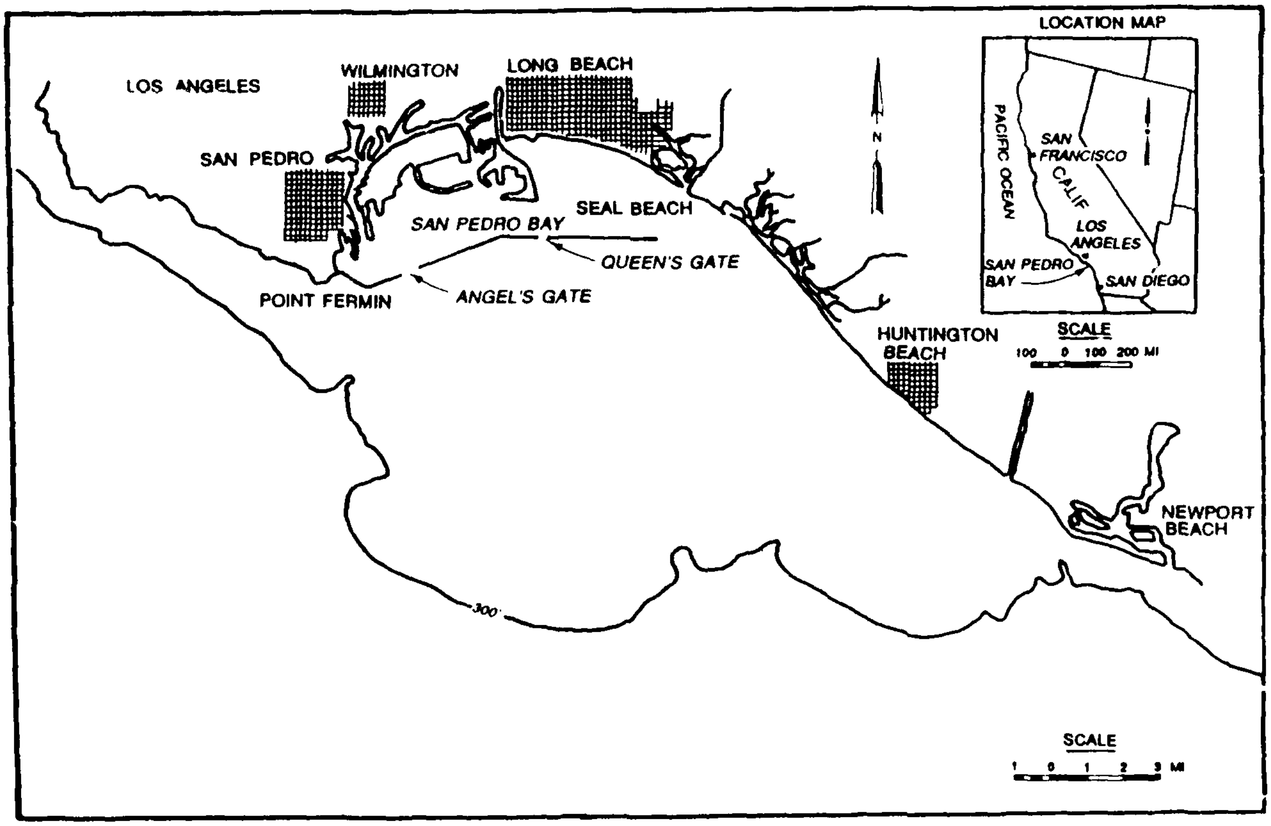

Figure 1. Project location

2. A distorted model (scale, 1:400 horizontal, 1:100 vertical) of the Los Angeles-Long Beach Harbors' complex was designed and constructed at the US Army Engineer Waterways Experiment Station (WES) in the early 1970's and is being used to determine the effects of long-period waves (30 to 400 sec) which lead to resonant harbor oscillations that can cause ship loading-unloading problems and downtime. The model distortion and scales, however, are inappropriate for short-period (4 to 25 sec) wind wave testing.

Model Study Objectives

3. At the request of the Port of Los Angeles, in coordination with the US Army Engineer District, Los Angeles (SPL), an undistorted hydraulic model, which includes a portion of Los Angeles Outer Harbor (Figure 2), was designed

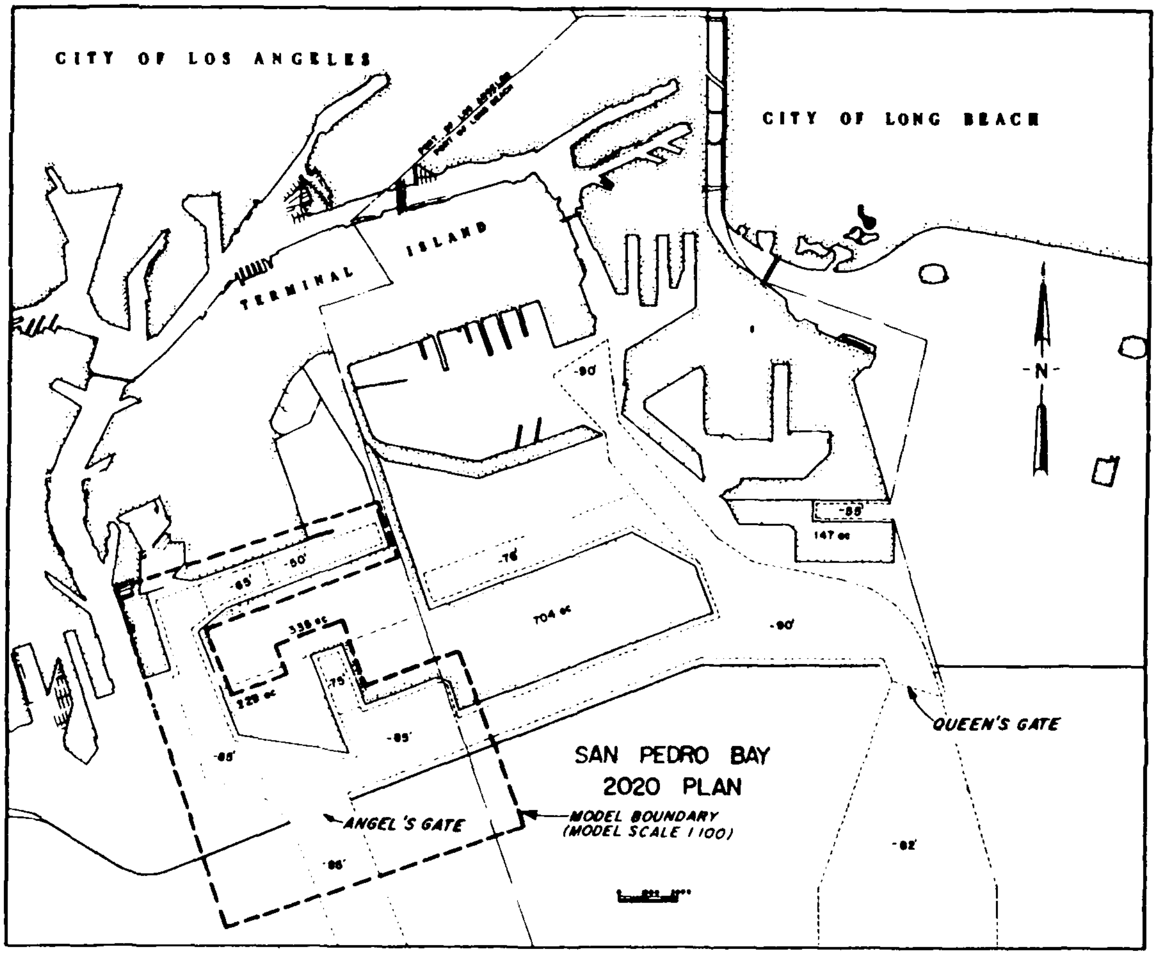

Figure 2. Approximate limits of proposed model relative to harbor

and constructed by WES' Coastal Engineering Research Center (CERC) to:

a. Determine short-period wave conditions in the entrance, in vessel maneuvering areas, and in berthing areas of the container ship and tanker terminals, during periods of storm-wave activity for proposed harbor development located near Angel's Gate.

b. Develop remedial plans to improve wave conditions as found necessary.

c. Determine if design modifications to the proposed plans could be made that would significantly reduce construction costs and still provide adequate protection.

Wave-Height Criteria

4. Completely reliable criteria have not yet been developed for ensuring satisfactory mooring conditions in harbors during attack by waves. For this study, however, the Port of Los Angeles and SPL specified that for an improvement plan to be acceptable, maximum wave heights were not to exceed 6.0 ft* at the tanker terminals and 1.5 ft at the container terminal locations.

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* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 3.

PART II: THE MODEL

Design of Model

5. The Los Angeles Outer Harbor Model (Figure 3) was constructed to an undistorted linear scale of 1:100, model to prototype. Scale selection was based on such factors as:

- a. Depth of water required in the model to prevent excessive bottom friction.
- b. Absolute size of model waves.
- c. Available shelter dimensions and area required for model construction.
- d. Efficiency of model operation.
- e. Available wave-generating and wave-measuring equipment.
- f. Model construction costs.

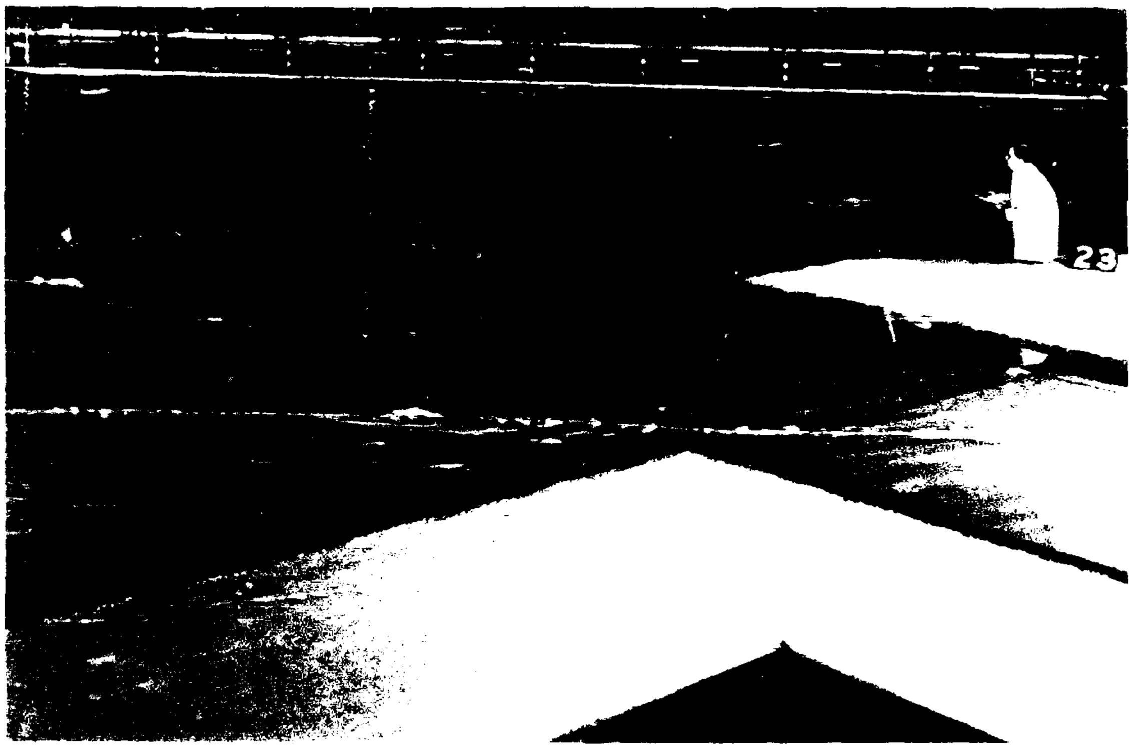

Figure 3. General view of model

A geometrically undistorted model was necessary to ensure accurate reproduction of short-period wave patterns including the effects of wave refraction, diffraction, and reflection. Following selection of the linear scale, the model was designed and operated in accordance with Froude's model law (Stevens

et al. 1942). The scale relations used for design and operation of the model were as follows:

Characteristic	Dimension*	Model-Prototype Scale Relations
Length	L	$L_r = 1:100$
Area	L^2	$A_r = L_r^2 = 10,000$
Volume	L^3	$V_r = L_r^3 = 100,000$
Time	T	$T_r = L_r^{1/2} = 1:10$
Velocity	L/T	$V_r = L_r^{1/2} = 1:10$

* Dimensions are in terms of length and time.

6. The existing breakwaters and proposed revetments at Los Angeles Harbor are rubble-mound structures. Experience and experimental research have shown that considerable wave energy passes through the interstices of this type structure; thus, the transmission and absorption of wave energy became a matter of concern in design of the 1:100-scale model. In small-scale hydraulic models, rubble-mound structures reflect relatively more and absorb or dissipate relatively less wave energy than geometrically similar prototype structures (Le Méhauté 1965). Also, the transmission of wave energy through a rubble-mound structure is relatively less for the small-scale model than for the prototype. Consequently, some adjustment in small-scale model rubble-mound structures is needed to ensure satisfactory reproduction of wave-reflection and wave-transmission characteristics. In past investigations (Dai and Jackson 1966, Brasfeild and Ball 1967) at WES, this adjustment was made by determining the wave-energy transmission characteristics of the proposed structure in a two-dimensional model using a scale large enough to ensure negligible scale effects. A cross-section then was developed for the small scale, three-dimensional model that would provide essentially the same relative transmission of wave energy. Therefore, from previous findings for structures and wave conditions similar to those at Los Angeles, it was determined that a close approximation of the correct wave-energy transmission characteristics would be obtained by increasing the size of the rock used in the 1:100-scale model to approximately two times that required for geometric similarity. Accordingly, in constructing the rubble-mound structures in the Los Angeles model, the rock sizes were computed linearly by scale, then

multiplied by 2 to determine the actual sizes to be used in the model.

The Model and Appurtenances

7. The model, which was molded in cement mortar, reproduced the proposed harbor expansion, Angel's Gate entrance, 2,800 and 5,100 ft of the San Pedro and Middle Breakwaters, respectively, and underwater contours in San Pedro Bay to an offshore depth of 60 ft with a sloping transition to the wave generator pit elevation* of -100 ft. The total area reproduced in the model was approximately 27,500 sq ft, representing about 10 square miles in the prototype. A model layout is shown in Figure 4. Vertical control for model construction was based on mean lower low water (mllw). Horizontal control was referenced to a local prototype grid system.

8. Model waves were generated by an 80-ft-long, unidirectional spectral wave generator with a trapezoidal-shaped, vertical motion plunger. The electrohydraulic wave generator utilized a hydraulic power supply, and the vertical motion of its plunger was controlled by a computer-generated command signal. The movement of the plunger caused a periodic displacement of water which generated the required test waves. The wave generator also was mounted on retractable casters which enabled it to be positioned to generate waves from the required directions.

9. An automated data acquisition and control system (ADACS), designed and constructed at WES (Figure 5), was used to generate and transmit control signals, monitor wave generator feedback, and secure and analyze wave-height data at selected locations in the model. Basically, through the use of a MICROVAX computer, ADACS recorded onto magnetic discs the electrical output of parallel-wire, resistance-type wave gages that measured the change in water-surface elevation with respect to time. The magnetic disc output of ADACS then was analyzed to obtain the wave-height data.

10. A 2-ft (horizontal) solid layer of fiber wave absorber was placed around the inside perimeter of the model to dampen wave energy that might otherwise be reflected from the model walls. In addition, guide vanes were placed along the wave generator sides in the flat pit area to ensure proper formation of the wave train incident to the model contours.

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* All elevations (el) cited herein are in feet referred to as mean lower low water (mllw) unless otherwise noted.

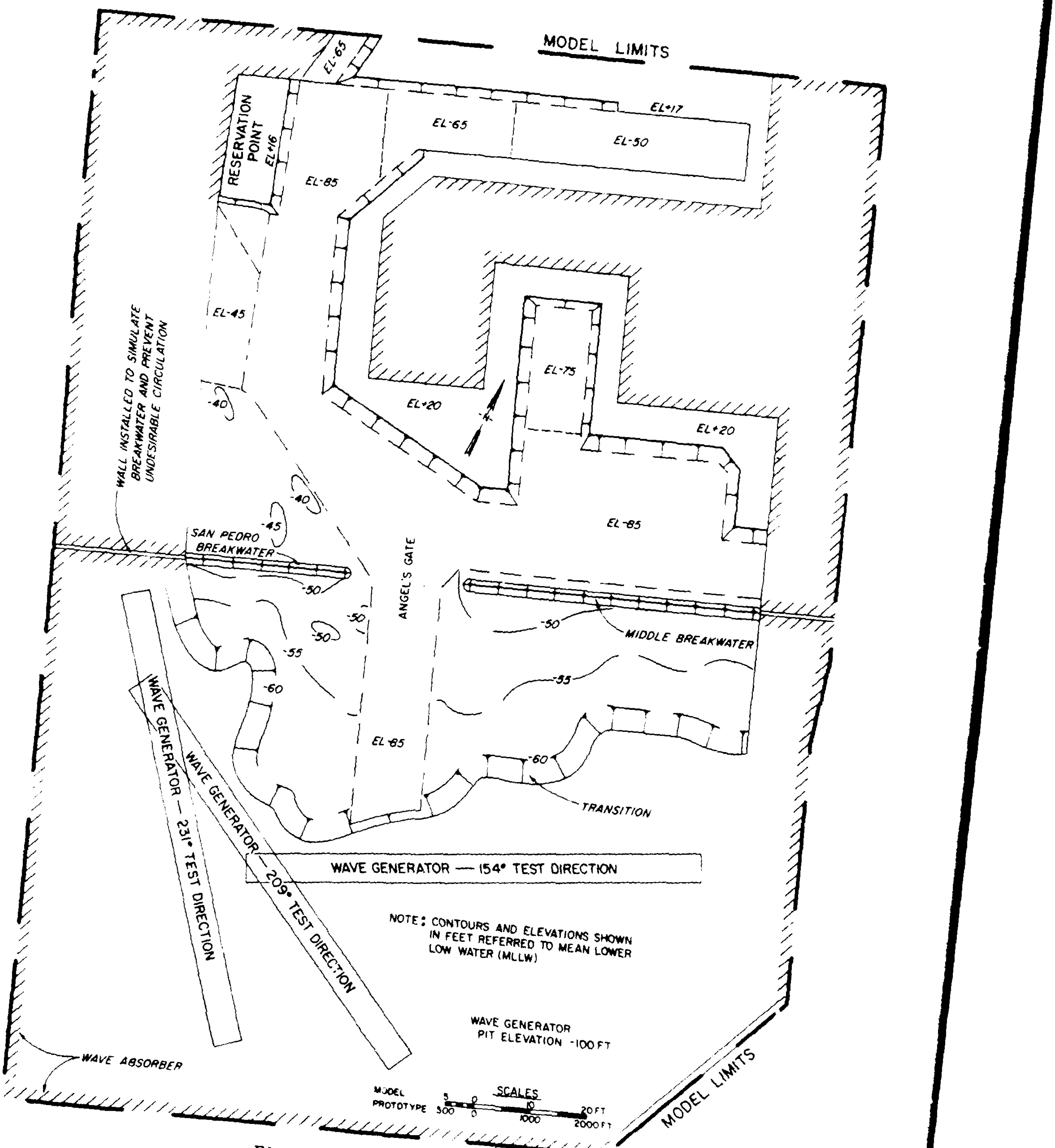

Figure 4. Model layout

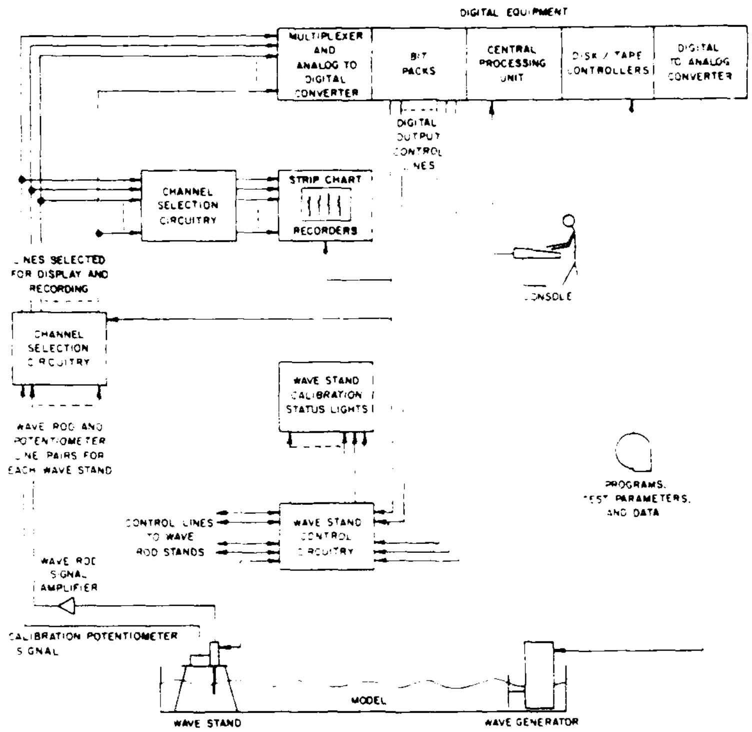

Figure 5. Automated data acquisition and control system

11. Although a model tanker of the proper scale was not available, limited navigation tests were conducted through the Los Angeles Harbor entrance with an existing 1:100-scale model ore carrier which was used in a previous study (Bottin 1983). The vessel (Figure 6) was 10 ft in length and represented a 1,000-ft-long prototype vessel. It was remotely controlled and equipped with (a) twin engines that could be operated independently and move the carrier in forward or reverse directions, (b) rudders behind each main engine propeller that were controlled together, and (c) bow and stern thrusters that could be operated independently and move the carrier in the port (left) or starboard (right) directions. When fully loaded (27.6-ft-draft), the model ship was capable of traveling in slack water at a forward speed equivalent to 14 mph in the prototype and of moving to the port or starboard directions at a speed equivalent to 2 mph in the prototype.

Figure 6. View of model ore carrier

PART III: TEST CONDITIONS AND PROCEDURES

Selection of Test Conditions

Still-water level

12. Still-water levels (swl's) for harbor wave action models are selected so that the various wave-induced phenomena that are dependent on water depths are accurately reproduced in the model. These phenomena include the refraction of waves in the project area, the overtopping of harbor structures by the waves, the reflection of wave energy from various structures, and the transmission of wave energy through porous structures.

13. In most cases, it is desirable to select a model swl that closely approximates the higher water stages which normally occur in the prototype for the following reasons:

- a. The maximum amount of wave energy reaching a coastal area normally occurs during the higher water phase of the local tidal cycle.
- b Most storms moving onshore are characteristically accompanied by a higher water level due to wind tide and shoreward mass transport.
- c. The selection of a high swl helps minimize model scale effects due to viscous bottom friction.
- d. When a high swl is selected, a model investigation tends to yield more conservative results.

14. An swl of +5.5 ft was selected by the Port of Los Angeles and SPL for use during model testing. This value (+5.5) represents mean higher high water in Los Angeles Outer Harbor.

Factors influencing selection of test wave characteristics

15. In planning the testing program for a model investigation of harbor wave-action problems, it is necessary to select dimensions and directions for the test waves that will allow a realistic test of proposed improvement plans and an accurate evaluation of the elements of the various proposals. Surface-wind waves are generated primarily by the interactions between tangential stresses of wind flowing over water, resonance between the water surface and atmospheric turbulence, and interactions between individual wave components. The height and period of the maximum wave that can be generated by a given storm depend on the wind speed, the length of time that wind of a given speed continues to blow, and the water distance (fetch) over which the wind blows.

Selection of test wave conditions entails evaluation of such factors as:

a. The fetch and decay distances (the latter being the distance over which waves travel after leaving the generating area) for various directions from which waves can attack the problem area.

b. The frequency of occurrence and duration of storm winds from the different directions.

c. The alignment, size, and relative geographic position of the navigation entrance to the harbor.

d. The alignments, lengths, and locations of the various reflecting surfaces inside the harbor.

e. The refraction of waves caused by differentials in depth in the area seaward of the harbor, which may create either a concentration or a diffusion of wave energy at the harbor site.

Wave refraction

16. When wind waves move into water of gradually decreasing depth, transformations take place in all wave characteristics except wave period (to the first order of approximation). The most important transformations with respect to the selection of test wave characteristics are the changes in wave height and direction of travel due to the phenomenon referred to as wave refraction. The change in wave height and direction may be determined by conducting a wave-refraction analysis. The shoaling coefficient, a function of wave length and water depth, can be obtained from the Shore Protection Manual (1984). When the refraction coefficient is determined, it is multiplied by the shoaling coefficient and gives a conversion factor for transfer of deepwater wave heights to shallow-water values.

17. Refraction and shoaling coefficients were obtained at Los Angeles Harbor for various wave periods from several deepwater wave directions and are presented in Table 1. Refraction coefficients were obtained from a past study involving transmission and overtopping of the harbor structures (Hales 1976) and represent an average of the values in the vicinity just outside Angel's Gate (approximately the location of the wave generator in the model). Shoaling coefficients were computed for a 105.5-ft water depth (100-ft pit elevation with 5.5-ft tide conditions superimposed) corresponding to the simulated depth at the model wave generator. The wave-height adjustment factor can be applied to any deepwater wave height to obtain the corresponding shallow-water value. Refracted directions, or directions of wave approach at the approximate locations of the wave generator in the model, were secured by analyzing refraction diagrams from Wilson et al. (1968). Based on these

results, three test directions representing seven deepwater directions were selected for use during model testing as shown below:

Deepwater Directions Represented Azimuth, deg	Selected Shallow-Water Test Direction, deg
West, 270	
West-southwest 247.5	
Southwest, 225	231
South-southwest, 202.5	
South, 180	209
South-southeast, 157.5	
Southeast, 135	154

The shallow-water wave directions selected represented the average of the refracted waves for the deepwater directions noted.

Prototype wave data and selection of test waves

18. Measured short-period prototype wave data on which a comprehensive statistical analysis of wave conditions could be based were unavailable for the Los Angeles Harbor area. However, statistical deepwater wave hindcast data representative of this area were obtained from the CERC Wave Information Studies by Corson et al. (1987). Deepwater data are summarized in Table 2. These data are representative of conditions west of the islands off the California coast. As deepwater waves approach Los Angeles Harbor from west counterclockwise through south, wave propagation is inhibited due to the offshore islands which partially shelter the harbor. Sheltering coefficients obtained at an adjacent site during another study (Hales 1987) were applied to these deepwater wave characteristics and resulted in deepwater wave conditions landward of the islands (Table 3). The data then were converted to shallow-water values by application of refraction and shoaling coefficients and are shown in Table 4. Characteristics of test waves used in the model (selected from Table 4) are shown in the following tabulation:

Shallow-Water Wave Direction, deg	Selected Test Waves Period, sec	Height, ft
231	5	4,10
	7	4,10,14
	9	4,10,14
	11	4,8,12
	13	4,8,12
	15	6,12
	17	4,8
209	7	8,12
	9	8,16
	11	6,10,16
	15	8
154	5	10
	7	8,12
	11	10
	15	10

Unidirectional wave spectra (based on JONSWAP parameters) for the selected test waves were generated and used throughout the model investigation. Plots of typical wave spectra are shown in Figure 7. The dashed line represents the desired spectra while the solid line represents the spectra generated by the wave generator. A typical incident wave train time-history also is shown in Figure 8, which depicts wave height (η) versus wave period.

Analysis of Model Data

19. Relative merits of the various plans tested were evaluated by a comparison of wave heights at selected locations in the model, and visual observations and wave pattern photographs. In the wave-height data analysis, the average height of the highest one third of the waves recorded at each gage location was computed. All wave heights then were adjusted to compensate for excessive model wave-height attenuation due to viscous bottom friction by application of Keulegan's equation (Keulegan 1950). From this equation, reduction of wave heights in the model (relative to the prototype) can be calculated as a function of water depth, width of wave front, wave period, water viscosity, and distance of wave travel.

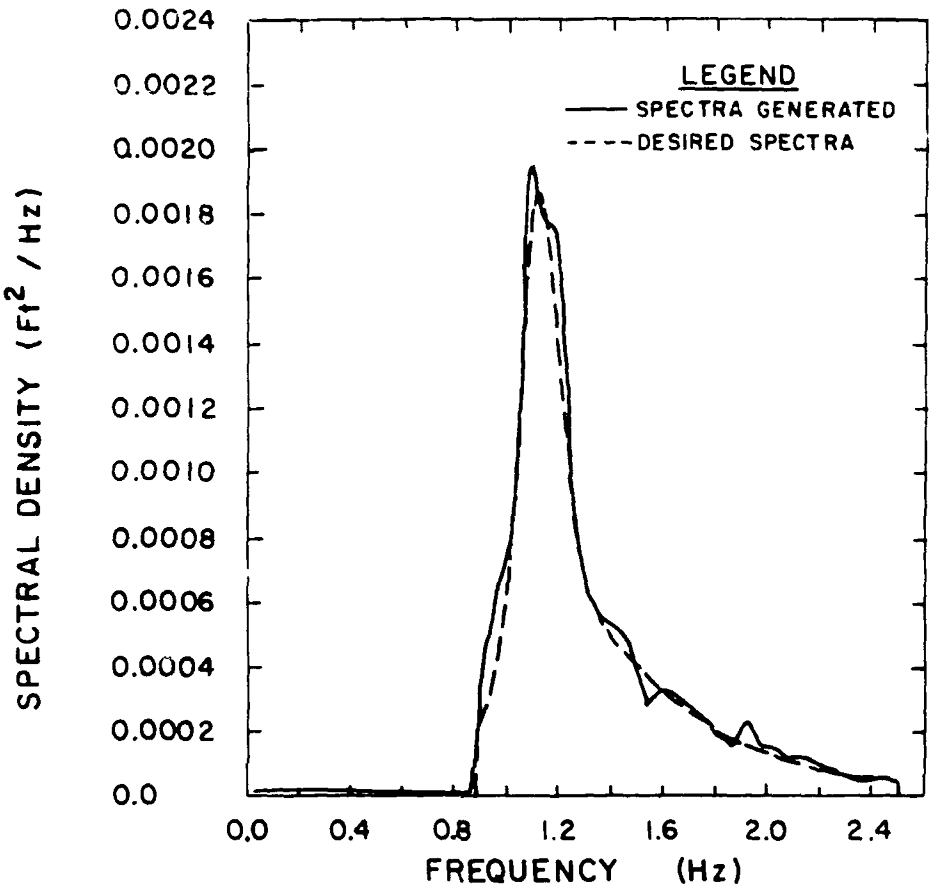

Figure 7. Typical wave spectra plot
(9-sec, 10-ft test waves)

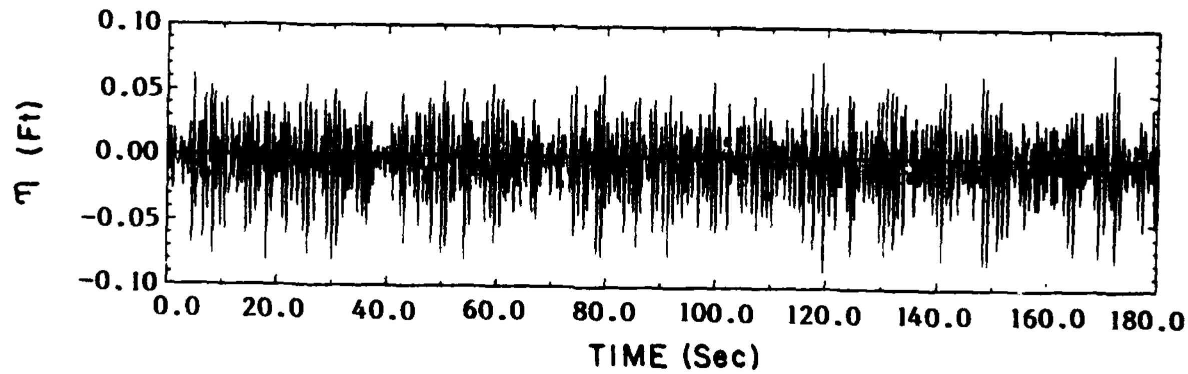

Figure 8. Typical wave train time history
(9-sec, 10-ft test waves)

PART IV: TESTS AND RESULTS

Tests

Test plans

20. Wave-height tests were conducted for the original harbor expansion as well as several test plan variations. These variations consisted of changes in the lengths, alignments, and cross sections of the existing breakwaters, and changes involving the proposed landfill configuration and side slopes of the proposed slips. Wave pattern photographs and videotape footage were obtained for representative test waves with some of the test plans installed. Brief descriptions of the improvement plans are presented in the following subparagraphs; dimensional details are presented in Plates 1-10.

a. Plan 1 (Plate 1) entailed the original outer harbor expansion of the ports 2020 Plan. It included a 1,200-ft-wide, 85-ft-deep entrance channel through Angel's Gate. A landfill north of the Middle Breakwater, provided for a 1,200-ft-wide channel leading to a maneuvering/turning basin north of the Middle Breakwater, both of which were 85 ft deep. A 1,000-ft-wide, 75-ft-deep mooring basin also was included north of the Middle Breakwater. The landfill was revetted with 1V:1.5H to 1V:1.75H slopes except where exposed to wave energy penetrating Angel's Gate where the slopes were flattened to 1V:2H.

b. Plan 2 (Plate 2) involved the elements of Plan 1 with a 200-ft westerly extension of the Middle Breakwater.

c. Plan 3 (Plate 2) included the elements of Plan 1, except the revetted slopes in the north end of the mooring basin and a portion of the slope close to the western limits of the model were flattened to 1V:3H.

d. Plan 4 (Plate 2) entailed the elements of Plan 1 with the 200-ft breakwater extension of Plan 2 and the 1V:3H revetted slopes of Plan 3.

e. Plan 5 (Plate 3) consisted of the elements of Plan 1 but the Middle Breakwater was sealed to prevent wave transmission.

f. Plan 6 (Plate 3) included the elements of Plan 1 with the sealed Middle Breakwater of Plan 5 and a 100-ft southerly extension of the landfill resulting in a 1,100-ft navigation opening between the Middle Breakwater and the landfill.

g. Plan 7 (Plate 4) entailed the elements of Plan 1 with the 200-ft Middle Breakwater extension of Plan 2 and the 100-ft landfill extension of Plan 6. The seal, however, was removed from the Middle Breakwater.

h. Plan 8 (Plate 4) consisted of the elements of Plan 1 with a 200-ft southerly extension of the landfill resulting in a 1,000-ft navigation opening between the Middle Breakwater and the landfill.

i. Plan 9 (Plate 5) involved the elements of Plan 1 with a spur breakwater originating at a point 300 ft west of the head of the San Pedro Breakwater and extending 600 ft in a southeasterly direction.

j. Plan 10 (Plate 5) included the elements of Plan 9, but the spur was extended an additional 300 ft southeasterly resulting in a 900-ft-long structure.

k. Plan 11 (Plate 5) consisted of the elements of Plan 9, but the spur was extended an additional 600 ft southeasterly resulting in a 1,200-ft-long structure.

l. Plan 12 (Plate 5) entailed the elements of Plan 9, but the spur was extended an additional 900 ft southeasterly resulting in a 1,500-ft-long structure.

m. Plan 13 (Plate 5) involved the elements of Plan 9, but the spur was extended an additional 1,200 ft southeasterly resulting in a 1,800-ft-long structure.

n. Plan 14 (Plate 6) consisted of the 1,800-ft-long spur breakwater of Plan 13 with a 200-ft westerly extension of the Middle Breakwater.

o. Plan 15 (Plate 6) included the elements of Plan 14, but the spur length was decreased to 1,500 ft.

p. Plan 16 (Plate 6) included the elements of Plan 14, but the spur length was decreased to 1,200 ft.

q. Plan 17 (Plate 6) involved the elements of Plan 14, but the spur length was decreased to 900 ft.

r. Plan 18 (Plate 6) entailed the elements of Plan 14, but the spur length was decreased to 600 ft.

s. Plan 19 (Plate 7) consisted of the elements of Plan 1, but the revetted slopes in the 1,000-ft-wide mooring area were replaced with vertical walls.

t. Plan 20 (Plate 8) entailed the elements of Plan 1, but the 1,000-ft-wide mooring basin north of the Middle Breakwater was decreased to 800 ft in width. The east side of the basin remained in the same place, and the landfill on the west of the basin was extended 200 ft easterly.

u. Plan 21 (Plate 8) involved the elements of Plan 1 with the 800-ft-wide mooring basin of Plan 20 and a 200-ft westerly extension of the Middle Breakwater.

v. Plan 22 (Plate 9) consisted of the elements of Plan 1, but 200 ft of the landfill north of the western end of the Middle Breakwater was removed resulting in a 1,400-ft navigation opening.

w. Plan 23 (Plate 9) entailed the 1,400-ft navigation opening of Plan 22 with a 200-ft westerly extension of the Middle Breakwater.

x. Plan 24 (Plate 10) consisted of the elements of Plan 1, with a 1,000-ft-wide inner basin installed east of Reservation Point. The northwest shoreline of the inner basin was revetted with 1V:1.5H side slopes for a distance of 3,410 ft. The remainder of the basin included vertical walls. Depths in the inner basin ranged from 50 to 65 ft.

Wave-height tests

21. Wave heights for the various plans of improvements were obtained for test waves from one or more of the directions listed in paragraph 17. Tests involving certain proposed improvement plans were limited to the most critical direction of wave approach (i.e. 209 deg). The original and the more promising improvement plans were tested comprehensively for waves from all test directions. Wave-gage locations for each improvement plan are shown in Plates 1-10.

Wave-pattern photographs and videotape

22. Wave-pattern photographs and videotape footage for the Los Angeles Harbor model were secured for selected test plans to aid in documentation of test results. These were furnished to the Port of Los Angeles and SPL for use in briefings, public meetings, etc.

Navigation tests

23. The 10-ft-long (1,000-ft-long prototype) vessel was used for navigation tests for the original harbor expansion entrance configuration (Plan 1) and the entrance configurations with the 1,100-ft and 1,000-ft openings between the proposed landfill and the Middle Breakwater (Plans 6 and 8, respectively). During the tests, the vessel approached the entrance at a speed of about 4.0 knots while under attack by 17-sec, 5-ft waves from 231 deg. Once in calm water, provided by the breakwaters, the carrier's engines were reversed to slow it down. The bow and stern thrusters on the vessel were used to simulate tug assistance during the tests. The path of the vessel through the entrance complex, its speed, and tug assistance were provided by the Port of Los Angeles.

Test Results

24. In evaluating test results, the relative merits of the various plans were based on an analysis of measured wave heights in the proposed

mooring areas. Model wave heights (significant wave height or $H_{1/3}$) were tabulated to show measured values at selected locations.

Test plans

25. Results of wave-height tests conducted for Plan 1 are presented in Table 5 for test waves from the three directions. Maximum wave heights were 13.6 ft in the entrance (Gage 1) for 9-sec, 16-ft test waves from 209 deg; 4.2 ft in the container terminal (Gages 7-11) for 9-sec, 16-ft and 11-sec, 16-ft test waves from 209 deg; and 10.3 ft in the tanker terminal (Gages 12 and 13) for 11-sec, 16-ft test waves from 209 deg. Representative wave patterns obtained for Plan 1 are shown in Photos 1-3.

26. Additional design wave-height data were obtained along the revetments of the various landfills (Gages 13-20) for Plan 1 for test waves from all three directions. Results of these tests are shown in Table 6. Maximum wave heights were 4.1 ft along the extreme western portion of the landfill (Gage 15) for 7-sec, 12-ft test waves from 154 deg; 15.3 ft along the area of the landfill exposed to waves from Angel's Gate (Gage 18) for 9-sec, 16-ft test waves from 209 deg; and 12.7 ft along the extreme eastern portion of the landfill (Gage 20) for 11-sec, 16-ft test waves from 209 deg.

27. Wave-height data obtained for Plans 2-4 for test waves from 209 deg are shown in Table 7. Maximum wave heights were 13.2, 12.8, and 12.7 ft in the entrance, 3.9, 3.7, and 3.5 ft in the container terminal; and 10.3, 8.9, and 9.1 ft in the tanker terminal for Plans 2-4, respectively. Typical wave patterns for Plan 2 are shown in Photo 4.

28. Wave heights obtained for Plans 5 and 6 are presented in Table 8. Maximum wave heights were 14.5 and 13.5 ft in the entrance; 3.9 and 3.4 ft in the container terminal; and 10.1 and 8.6 ft in the tanker terminal for Plans 5 and 6, respectively.

29. Results of wave-height tests for Plans 7 and 8 are shown in Table 9 for test waves from 209 deg. Maximum wave heights obtained were 13.7 and 14.4 ft in the entrance; 4.1 and 4.2 ft in the container terminal; and 9.9 and 10.0 ft in the tanker terminal. Typical wave patterns for Plans 7 and 8 are shown in Photos 5 and 6, respectively.

30. Wave-height test results for Plans 9-13 are presented in Table 10 for test waves from 209 deg. Maximum wave heights were 10.7, 7.7, 5.6, 5.6, and 5.3 ft in the entrance; 4.1, 3.4, 3.3, 3.1, and 3.2 ft in the container terminal; and 8.1, 7.0, 7.1, 6.8, and 6.8 ft in the tanker terminal for

Plans 9-13, respectively. Typical wave patterns for Plans 9-13 are shown in Photos 7-11.

31. Wave heights obtained for Plans 14-18 for test waves from 209 deg are presented in Table 11. Maximum wave heights obtained were 5.3, 5.9, 5.5, 7.0, and 11.8 in the entrance; 2.8, 3.0, 3.2, 3.7, and 4.0 ft in the container terminal; and 6.0, 6.2, 6.4, 7.2, and 8.1 ft in the tanker terminal for Plans 14-18, respectively. Representative wave patterns obtained for Plan 18 are shown in Photos 12-16.

32. Results of wave-height tests for Plans 9 and 18 for representative waves from 231 deg are shown in Table 12. Maximum wave heights were 5.5 ft in the entrance and 1.1 ft in the container terminal for both test plans. In the tanker terminal, maximum wave heights were 4.2 ft and 3.8 ft, respectively, for Plans 9 and 18. Typical wave patterns for Plans 9 and 18 for test waves from 231 deg are shown in Photos 17 and 18, respectively.

33. Wave-height data secured with Plan 19 installed in the model are presented in Table 13 for test waves from 209 deg. Maximum wave heights were 14.5 ft in the entrance, 9.0 ft in the container terminal, and 11.8 ft in the tanker terminal. Wave energy reflecting from the vertical walls in the container terminal area resulted in extremely rough and turbulent wave conditions. Typical wave patterns for Plan 19 are shown in Photo 17, and a comparison of wave patterns for Plans 1 and 19 are shown in Photo 20.

34. Wave heights obtained for Plans 20 and 21 for test waves from 209 deg are presented in Table 14. Maximum wave heights obtained were 13.3 ft in the entrance for both plans; 2.6 and 2.5 ft in the container terminal; and 8.2 and 8.3 ft in the tanker terminal for Plans 20 and 21, respectively. Representative wave patterns obtained for Plans 20 and 21 are shown in Photos 21 and 22, respectively.

35. Results of wave-height tests for Plan 20 for test waves from 231 and 154 deg are presented in Table 15. Maximum wave heights were 14.3 ft in the entrance for 9-sec, 14-ft test waves from 209 deg; 2.5 ft in the container terminal for 15-sec, 10-ft waves from 154 deg; and 6.6 ft in the tanker terminal for 11-sec, 12-ft test waves from 231 deg. Typical wave patterns for Plan 20 depicting waves from 231 and 154 deg are shown in Photos 23 and 24, respectively.

36. Wave-height test results for Plans 22 and 23 for test waves from 209 deg are presented in Table 16. Maximum wave heights were 14.3 and 13.4 ft in the entrance; 4.8 and 4.5 ft in the container terminal; and 11.3 and

10.5 ft in the tanker terminal for Plans 22 and 23, respectively. Wave patterns obtained for Plans 22 and 23 are shown in Photos 25 and 26, respectively, for test waves from 209 deg.

37. Wave heights obtained for Plan 22 for test waves from 231 and 154 deg are presented in Table 17. Maximum wave heights were 13.9 ft in the entrance for 9-sec, 14-ft test waves from 231 deg; 2.7 ft in the container terminal for 7-sec, 12-ft waves from 154 deg; and 7.3 ft in the tanker terminal for 11-sec, 12-ft test waves from 231 deg. Representative wave patterns for Plan 22 are shown in Photos 27 and 28 for test waves from 231 and 154 deg, respectively.

38. Wave heights obtained in the inner basin of Plan 24 are shown in Table 18 for test waves from all three test directions. Maximum wave heights were 1.7 ft in the container terminal mooring area (Gage 31) for 11-sec, 10-ft test waves from 154 deg. Typical wave patterns of the interior basin of Plan 24 are shown in Photo 29.

Discussion of test results

39. Results of wave-height tests for all the harbor expansion plans indicated that the wave-height criteria at the tanker terminals (Gages 12 and 13) and/or the container terminal locations (Gages 7-11) would be exceeded at times. In an effort to determine the most effective improvement plans, wave conditions in the various terminals were evaluated by the average time (hours per year) in which the established wave-height criteria were exceeded. The data in Table 19 were developed from wave hindcast tables. Note that waves approach Los Angeles Harbor on an average of 626.4 hours per year from 231 deg, 8.25 hours per year from 209 deg, and 2.1 hours per year from 154 deg.

40. Wave-height tests for the original harbor expansion plan (Plan 1) revealed that maximum wave heights in the tanker terminal were 10.3 ft, or 4.3 ft in excess of the established 6.0-ft wave-height criterion in this location. In the container terminal maximum wave heights were 4.2 ft, or 2.7 ft above the established 1.5-ft wave-height criterion. Also, based on Table 19, the 6.0-ft wave-height criterion in the tanker terminal would be exceeded about 7.35 hours per year, on the average, and the 1.5-ft criterion in the container terminal would be exceeded approximately 21.45 hours per year annually.

41. Wave heights for Plans 2-4 indicated that installation of the absorbors in the basins adjacent to the terminals (Plan 3) slightly reduced

maximum wave heights in the terminals for test waves from 209 deg. Wave heights in the tanker terminal were reduced from 10.3 to 8.9 ft, and wave heights in the container terminal from 4.2 to 3.7 ft. The wave conditions were, however, substantially higher than the established criterion values of 6.0 and 1.5 ft. In addition, from 209 deg, waves would exceed the criterion in the terminal locations, on an average, the same hours per year as the original expansion plan (Plan 1).

42. Sealing of the Middle Breakwater (Plans 5 and 6) and an extension of the proposed landfill narrowing the navigation opening between the landfill and Middle Breakwater (Plan 6) also resulted in slightly reduced maximum wave heights in the terminal locations when compared to the original plan (Plan 1). Maximum wave heights for Plan 6 were 3.4 ft as opposed to 4.2 ft for Plan 1 in the container terminal and 8.6 ft as opposed to 10.3 ft in the tanker terminal. These values also were substantially higher than the established criteria. The sealed Middle Breakwater did result in wave heights in the container terminal within the established criterion, however, a greater percentage of the time for waves from 209 and 154 deg. For these directions wave heights will exceed the 1.5-ft criterion 5.85 hours per year for Plan 5 as opposed to 8.7 hours per year for Plan 1, on an average.

43. Neither the 100-ft westerly Middle Breakwater extension and 100-ft landfill extension of Plan 7 nor the 200-ft landfill extension of Plan 8 were effective in significantly reducing maximum wave heights in the vessel terminals. Maximum heights in the container terminal were 4.1 and 4.2 ft for Plans 7 and 8, respectively, versus 4.2 ft for Plan 1; and maximum wave heights in the tanker terminal were 9.9 and 10.0 ft, respectively, versus 10.3 ft for Plan 1.

44. Wave-height tests for 209 deg for the spur breakwaters originating from San Pedro Breakwater (Plans 9-13) revealed maximum wave heights of 3.2 ft in the container terminal and 6.8 ft in the tanker terminal for the 1,800-ft-long structure (Plan 13). A 200-ft westerly extension of the Middle Breakwater, in conjunction with the 1,800-ft-long spur (Plan 14), reduced maximum wave heights to 2.8 and 6.0 ft in the container and tanker terminals, respectively, for test waves from 209 deg. The 6.0-ft criterion was met for 209 deg for Plan 14 in the tanker terminal, and wave conditions would exceed the criterion at this location about 0.15 hour per year for Plan 13 as opposed to 3.0 hours per year for the original harbor expansion (Plan 1). In the container terminal wave heights would exceed the 1.5-ft criterion about

3.45 hours per year for Plan 13 and 2.7 hours per year for Plan 14 versus 6.75 hours per year for Plan 1, on the average, for test waves from 209 deg. For test waves from 231 deg, even the 600-ft spurs of Plans 9 and 18 would result in waves within the established criteria at the container and tanker terminals for all wave conditions. For test waves from 154 deg, it is anticipated that the spurs would have a negligible effect on waves transmitting through the Middle Breakwater, and the container terminal criterion probably would be exceeded about 1.95 hours per year (same as Plan 1). In summary, the 1,800-ft-long San Pedro spur with the 200-ft-long westerly extension of the Middle Breakwater (Plan 14) appeared to be most effective with regard to wave conditions in the vessel mooring areas. Wave heights would exceed the 1.5-ft criterion in the container terminal about 4.65 hours per year for Plan 14 for all wave directions versus 21.45 hours per year for Plan 1; and wave heights in the tanker terminal would meet the 6.0-ft criterion for all wave conditions versus 7.35 hours per year that they would be exceeded for Plan 1.

45. The installation of vertical walls in the outer slip (Plan 19) resulted in maximum wave heights of 9.0 ft in the container terminal and 11.8 ft in the tanker terminal. Maximum wave heights in the container terminal for Plan 19 more than doubled when compared to Plan 1 wave heights. All wave conditions from 209 deg resulted in wave heights in the container terminal that would exceed the established 1.5-ft criterion. Wave pattern photos and visual observations also indicated rough and turbulent conditions in the outer slip.

46. Wave-height test results for the 800-ft-wide outer basin (Plan 20) indicated maximum wave heights of 2.6 ft in the container terminal and 8.2 ft in the tanker terminal for test waves from 209 deg. Based on the frequency of occurrence of the wave conditions that produced these maximum wave heights, however, and considering test waves from all directions, the established 1.5-ft wave-height criterion in the container terminal for Plan 20 will be exceeded approximately 3.45 hours per year versus 21.45 hours per year for the original Plan 1 expansion plan. Also, the established 6.0-ft wave-height criterion in the tanker terminal will be exceeded about 4.2 hours per year for Plan 20 versus 7.35 hours per year for Plan 1. Based on the degree of wave protection in the vessel terminals and cost considerations, it appeared that Plan 20 was the optimum plan tested to this point in the model investigation. A 200-ft westerly extension of the Middle Breakwater with the 800-ft-wide

outer slip (Plan 21) resulted in no significant increase in wave protection in the vessel terminal areas.

47. Wave-height tests with the 1,400-ft-wide navigation channel between the proposed landfill and the Middle Breakwater (Plan 22) indicated an increase in maximum wave heights in the terminal areas as opposed to the originally proposed 1,200-ft-wide opening of Plan 1. Wave heights of 4.8 ft (versus 4.2 ft for Plan 1) and 11.3 ft (versus 10.3 ft for Plan 1) were recorded in the container and tanker terminals, respectively. Wave heights would exceed the established criterion in the tanker terminal an average of 18.45 hours per year for Plan 22 (versus 7.35 hours per year for Plan 1); and the criterion in the container terminal for Plan 18 would be exceeded on an average of 21.9 hours per year (versus 21.45 hours per year for Plan 1). A 200-ft westerly extension of the Middle Breakwater (Plan 23) would slightly, but not significantly, improve wave conditions in the container and tanker terminal areas.

48. Wave-height data obtained in the inner basin of Plan 24 revealed that maximum wave heights would exceed the established 1.5-ft wave-height criterion at one location (Gage 31) for only one test wave condition. The criterion was exceeded by 0.2 ft, and the corresponding test wave condition will occur on an average of 0.15 hour per year. Wave conditions in other areas of the inner basin were well within the established criterion.

49. Navigation tests conducted for 1,200-, 1,100-, and 1,000-ft navigation openings between the proposed landfill and the Middle Breakwater (Plans 1, 6, and 8, respectively) revealed the vessel could navigate either entrance plan for 5-ft wave conditions. The wider openings were less difficult to maneuver and provided for a greater margin of error. During these tests every effort was made to operate the model ore carrier as the prototype tanker will be operated at the port. Ship handling characteristics may not be the same in the prototype, but, for these tests, relative comparisons between the various test plans were considered valid.

PART V: CONCLUSIONS

50. Based on the results of the hydraulic model investigation reported herein, it is concluded that:

- a. The originally proposed outer harbor expansion plan (Plan 1) will result in wave heights that will exceed the established criteria of 6.0 ft in the tanker terminal and 1.5 ft in the container terminal a small percentage of the time. Maximum wave heights obtained were greater than 10 and 4 ft in the tanker and container terminals, respectively. The criterion will be exceeded on an average of 7.35 hours per year in the tanker terminal and 21.45 hours per year in the container terminal.
- b. Sealing of the Middle Breakwater (Plan 5) will result in slightly improved wave conditions in the container terminal of the outer slip for test waves from 209 and 154 deg.
- c. A 200-ft westerly extension of the Middle Breakwater (used for several test plans) will slightly, but not significantly, reduce wave heights in vessel terminal areas.
- d. Decreasing the navigation width between the proposed landfill and Middle Breakwater from 1,200 to 1,000 ft (Plan 8) will not significantly reduce wave heights at the terminals; however, an increase of the navigation opening to 1,400 ft (Plan 22) will substantially increase wave conditions in these areas.
- e. The 1,800-ft-long San Pedro Breakwater spur in conjunction with a 200-ft westerly extension of the Middle Breakwater (Plan 14) will result in wave heights that exceed the established criterion in the container terminal and that meet the criterion in the tanker terminal areas. Maximum wave heights obtained in the container terminal were about 3 ft, but the criterion at this location will be exceeded on an average of only about 4.65 hours per year.
- f. The installation of vertical walls in the southern slip (Plan 19) will result in very rough and confused wave conditions in the container terminal due to wave reflections with wave heights up to 9 ft at this location.
- g. Reducing the southern slip basin width from 1,000 to 800 ft (Plan 20) will result in wave heights that exceed the established criterion in the container and tanker terminals; however, wave heights were of less magnitude than the original Plan 1 expansion configuration and the criteria would be exceeded a smaller percentage of the time. Maximum wave heights were 8.2 and 2.6 ft in the tanker and container terminals, respectively. It is estimated the established 1.5-ft criterion in the container terminal would be exceeded on an average of 3.45 hours per year, and the 6.0-ft criterion in the tanker terminal exceeded about 4.2 hours per year.
- h. The revetted/vertical wall northern slip configuration (Plan 24) will result in the established 1.5-ft wave-height

criterion being exceeded by only 0.2 ft at one mooring location for only one wave condition. This condition will occur on an average of only 0.15 hour per year.

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Table 1

Summary of Refraction and Shoaling Analysis at Angel's Gate, Los Angeles Harbor, California

Deepwater Direction deg	Wave Period sec	Refraction Coefficient	Shoaling* Coefficient	Wave-Height Adjustment Factor
W, 270.0	9	0.45	0.937	0.422
	11	0.45	0.913	0.411
	13	0.45	0.920	0.414
	15	0.46	0.941	0.433
	17	0.46	0.969	0.446
	19	0.47	1.001	0.470
WSW, 247.5	5	1.00	1.000	1.000
	7	0.72	0.980	0.706
	9	0.74	0.937	0.693
	11	0.70	0.913	0.639
	13	0.69	0.920	0.635
	15	0.69	0.941	0.649
	17	0.67	0.969	0.649
	19	0.67	1.001	0.671
SW, 225.0	5	1.00	1.000	1.000
	7	0.94	0.980	0.921
	9	0.94	0.937	0.881
	11	0.91	0.913	0.831
	13	0.79	0.920	0.727
	15	0.70	0.941	0.659
	17	0.60	0.969	0.581
	19	0.59	1.001	0.591
SSW, 202.5	5	1.00	1.000	1.000
	7	0.99	0.980	0.970
	9	1.10	0.937	1.031
	11	1.13	0.913	1.032
	13	1.03	0.920	0.948
	15	0.93	0.941	0.875
	17	0.85	0.969	0.824
	19	0.78	1.001	0.781

(Continued)

* At 105.5-ft depth (100-ft pit elevation with 5.5-ft tide superimposed).

Table 1 (Concluded)

Deepwater Direction deg	Wave Period sec	Refraction Coefficient	Shoaling Coefficient	Wave-Height Adjustment Factor
S, 180.0	5	1.00	1.000	1.000
	7	0.97	0.980	0.951
	9	1.01	0.937	0.946
	11	0.83	0.913	0.758
	13	0.75	0.920	0.690
	15	1.12	0.941	1.054
	17	1.38	0.969	1.337
	19	1.29	1.001	1.291
SSE, 157.5	5	1.00	1.000	1.000
	7	1.18	0.980	1.156
SE, 135.0	5	1.00	1.000	1.000

Table 2

Estimated Magnitude of Unsheltered Deepwater Waves (Sea and Swell) Approaching

Los Angeles-Long Beach Harbors from the Directions Indicated

	Occurrences* per Wave Period, sec							
Wave Height, ft	4.4-6.0	6.1-8.0	8.1-10.5	10.6-11.7	11.8-13.3	13.4-15.3	15.4-18.1	Total
				West				
0.0- 3.3	26	3	32	4	--	--	--	65
3.3- 6.6	31	97	395	112	29	--	--	664
6.6- 9.8	34	57	367	439	252	82	--	1,231
9.8-13.1	--	37	65	209	595	136	3	1,045
13.1-16.4	--	1	12	27	191	267	5	503
16.4-19.7	--	--	2	--	11	68	17	98
19.7-23.0	--	--	--	--	--	6	8	14
23.0-26.2	--	--	--	--	--	4	--	4
Total	91	195	873	791	1,078	563	33	3,624
				West-Southwest				
0.0- 3.3	6	2	--	--	--	--	--	8
3.3- 6.6	--	6	47	--	--	--	--	53
6.6- 9.8	4	6	67	32	24	1	--	134
9.3-13.1	--	16	41	24	42	8	--	131
13.1-16.4	--	5	13	13	42	--	--	73
16.4-19.7	--	--	19	3	3	11	--	36
19.7-23.0	--	--	--	--	--	3	--	3
Total	10	35	187	72	111	23	--	438

(Continued)

* Occurrences compiled for period 1956-1975. Each occurrence represents a 3-hr duration.

(Sheet 1 of 3)

Table 2 (Continued)

Wave Height, ft	Occurrences per Wave Period, sec							
	4.4-6.0	6.1-8.0	8.1-10.5	10.6-11.7	11.8-13.3	13.4-15.3	15.4-18.1	Total
Southwest								
0.0- 3.3	--	--	--	--	--	--	--	--
3.3- 6.6	--	5	16	--	--	--	--	21
6.6- 9.8	--	6	14	--	1	5	--	26
9.8-13.1	--	25	13	3	5	1	--	47
13.1-16.4	--	4	9	--	5	--	--	18
16.4-19.7	--	--	1	1	--	--	--	2
Total	--	40	53	4	11	6	--	114
South-Southwest								
0.0- 3.3	--	--	--	--	--	--	--	--
3.3- 6.6	--	--	--	--	--	--	--	--
6.6- 9.8	--	1	3	1	--	2	--	7
9.8-13.1	--	7	7	--	--	--	--	14
13 1-16.4	--	2	5	--	--	--	--	7
16.4-19.7	--	--	1	1	--	--	--	2
19.7-23.0	--	--	4	--	--	--	--	4
Total	--	10	20	2	--	2	--	34
South								
0.0- 3.3	--	--	--	--	--	--	--	--
3.3- 6.6	--	--	--	--	--	--	--	--
6.6- 9.8	--	1	--	1	--	1	--	3
9.8-13.1	--	3	8	--	--	--	--	11
13.1-16.4	--	1	5	--	--	--	--	6
16.4-19.7	--	--	1	--	--	--	--	1
Total	--	5	14	1	--	1	--	21

(Continued)

Table 2 (Concluded)

Wave Height, ft	Occurrences per Wave Period, sec							
	4.4-6.0	6.1-8.0	8.1-10.5	10.6-11.7	11.8-13.3	13.4-15.3	15.4-18.1	Total
South-Southeast								
0.0-3.3	--	--	--	--	--	--	--	--
3.3-6.6	--	4	--	--	--	--	--	4
6.6-9.8	--	1	--	--	--	1	--	2
Total	--	5	--	--	--	1	--	6
Southeast								
0.0-3.3	--	--	--	--	--	--	--	--
3.3-6.6	--	--	--	--	--	--	--	--
6.6-9.8	1	6	--	1	--	--	--	8
Total	1	6	--	1	--	--	--	8

(Sheet 3 of 3)

Table 3

Estimated Magnitude of Sheltered Deepwater Waves (Sea and Swell) Approaching Los Angeles-Long Beach Harbors from the Directions Indicated

Wave Height, ft	Occurrences* per Wave Period, sec 4.4-6.0	6.1-8.0	8.1-10.5	10.6-11.7	11.8-13.3	13.4-15.3	15.4-18.1	Total
West								
0- 4	26	3	32	4	--	--	--	65
4- 6	31	97	395	112	29	--	--	664
6- 8	34	57	367	439	252	82	--	1,231
8-10	--	37	65	209	595	136	3	1,045
10-12	--	1	12	27	191	267	5	503
12-14	--	--	--	--	--	--	--	--
14-16	--	--	2	--	11	68	17	98
16-18	--	--	--	--	--	10	8	18
Total	91	195	873	791	1,078	563	33	3,624
West-Southwest								
0- 4	6	2	--	--	--	--	--	8
4- 6	--	6	47	--	--	--	--	53
6- 8	--	--	--	--	--	--	--	--
8-10	4	6	67	32	24	1	--	134
10-12	--	16	41	24	42	8	--	131
12-14	--	--	--	--	--	--	--	--
14-16	--	5	13	13	42	--	--	73
16-18	--	--	19	3	3	14	--	39
Total	10	35	187	72	111	23	--	438

(Continued)

* Occurrences compiled for period 1956-1975. Each occurrence represents a 3-hr duration.

Table 3 (Concluded)

Wave Height, ft	Occurrences per Wave Period, sec 4.4-6.0	6.1-8.0	8.1-10.5	10.6-11.7	11.8-13.3	13.4-15.3	15.4-18.1	Total
Southwest								
0- 4	--	--	--	--	--	--	--	--
4- 6	--	5	16	--	--	--	--	21
6- 8	--	--	--	--	--	--	--	--
8-10	--	6	14	--	1	5	--	26
10-12	--	25	13	3	5	1	--	47
12-14	--	4	9	--	5	--	--	18
14-16	--	--	1	1	--	--	--	2
Total	--	40	53	4	11	6	--	114
South-Southwest								
0- 4	--	--	--	--	--	--	--	--
4- 6	--	--	--	--	--	--	--	--
6- 8	--	1	3	1	--	2	--	7
8-10	--	7	7	--	--	--	--	14
10-12	--	2	5	--	--	--	--	7
12-14	--	--	1	1	--	--	--	2
14-16	--	--	4	--	--	--	--	4
Total	--	10	20	2	--	2	--	34
South								
0-4	--	--	--	--	--	--	--	--
4-6	--	1	--	1	--	1	--	3
6-8	--	4	14	--	--	--	--	18
Total	--	5	14	1	--	1	--	21

Table 4

Estimated Magnitude of Shallow-Water Waves (Sea and Swell) Approaching Los Angeles Harbor Entrance from the Directions Indicated

Wave Height, ft		Occurrences* per Wave Period, sec							
		4.4-6.0	6.1-8.0	8.1-10.5	10.6-11.7	11.8-13.3	13.4-15.3	15.4-18.1	Total
					West				
0-4		91	157	794	555	281	82	--	1,960
4-6		--	38	77	236	786	403	8	1,548
6-8		--	--	2	--	11	78	25	116
	Total	91	195	873	791	1,078	563	33	3,624
					West-Southwest				
0- 4		6	2	--	--	--	--	--	8
4- 6		--	6	47	--	--	--	--	53
6- 8		--	6	67	56	66	9	--	204
8-10		4	16	41	--	--	--	--	61
10-12		--	5	13	16	45	14	--	93
12-14		--	--	19	--	--	--	--	19
	Total	10	35	187	72	111	23	--	438
					Southwest				
0- 4		--	--	--	--	--	--	--	--
4- 6		--	--	16	--	--	--	--	16
6- 8		--	5	--	--	1	6	--	12
8-10		--	6	14	3	5	--	--	28
10-12		--	25	13	1	5	--	--	44
12-14		--	4	10	--	--	--	--	14
	Total	--	40	53	4	11	6	--	114

(Continued)

* Occurrences compiled for period 1956-1975. Each occurrence represents a 3-hr duration.

Table 4 (Concluded)

Wave Height, ft		Occurrences per Wave Period, sec							
		4.4-6.0	6.1-8.0	8.1-10.5	10.6-11.7	11.8-13.3	13.4-15.3	15.4-18.1	Total
South-Southwest									
0- 4		--	--	--	--	--	--	--	--
4- 6		--	--	--	--	--	-	--	--
6- 8		--	1	--	--	--	2	--	3
8-10		--	7	3	1	--	--	--	11
10-12		--	2	7	--	--	--	--	9
12-14		--	--	5	--	--	--	--	5
14-16		--	--	5	1	--	--	--	6
	Total	--	10	20	2	--	2	--	34
South									
0-4		--	--	--	--	--	--	--	--
4-6		--	1	--	1	--	--	--	2
6-8		--	4	14	--	--	1	--	19
	Total	--	5	14	1	--	1	--	21
South-Southeast									
0- 4		--	--	--	--	--	--	--	--
4- 6		--	--	--	--	--	--	--	--
6- 8		--	4	--	--	--	--	--	4
8-10		--	--	--	--	--	1	--	1
10-12		--	1	--	--	--	--	--	1
	Total	--	5	--	--	--	1	--	6
Southeast									
0- 4		--	--	--	--	--	--	--	--
4- 6		--	--	--	--	--	--	--	--
6- 8		--	--	--	--	--	--	--	--
8-10		1	6	--	1	--	--	--	8
	Total	1	6	--	1	--	--	--	8

Table 5

Wave Heights for Plan 1 for Test Waves

from 231, 209, and 154 deg

Test Wave		Wave Height, ft												
Period sec	Height ft	Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13
							231 deg							
5	4	1.7	0.1	0.3	0.6	0.9	1.1	0.2	0.1	0.1	0.1	0.2	0.3	0.4
	10	6.4	0.2	1.1	2.2	4.4	2.8	0.6	0.2	0.2	0.3	0.4	1.8	2.8
7	4	2.4	0.1	0.5	1.1	1.5	1.0	0.7	0.2	0.1	0.2	0.3	0.6	0.7
	10	7.7	0.2	1.5	3.2	5.1	3.2	1.0	0.2	0.4	0.4	0.8	2.3	2.9
	14	10.0	0.3	2.5	4.9	7.5	4.0	1.3	0.3	0.6	0.8	1.3	3.7	4.6
9	4	3.9	0.2	0.8	2.2	2.7	1.4	0.5	0.2	0.5	0.4	0.5	1.3	1.7
	10	9.1	0.3	1.6	4.8	6.4	3.4	1.1	0.4	1.0	0.8	1.1	3.3	4.5
	14	12.9	0.5	2.5	6.4	9.7	4.6	1.7	0.9	1.5	1.2	1.8	5.1	6.8
11	4	3.6	0.2	0.9	2.6	2.6	1.5	0.7	0.4	0.6	0.4	0.6	1.8	2.3
	8	7.5	0.3	1.8	4.8	5.3	3.0	1.2	0.6	0.9	0.6	0.9	3.6	4.6
	12	10.2	0.4	2.7	6.2	6.9	3.9	1.7	0.9	1.1	0.9	1.1	4.7	6.0
13	4	3.8	0.4	1.4	3.0	3.0	1.5	0.7	0.3	0.5	0.3	0.6	1.9	2.1
	8	6.0	0.4	2.2	4.5	4.8	2.1	1.0	0.4	0.6	0.4	0.8	2.9	3.3
	12	9.0	0.5	3.5	6.2	7.3	3.2	1.4	0.7	0.9	0.9	1.1	4.2	5.0
15	6	4.2	0.3	1.8	3.2	3.7	1.8	0.9	0.4	0.4	0.4	0.7	1.9	2.2
	12	8.3	0.6	3.4	5.4	7.1	3.0	1.6	0.8	0.9	1.0	1.4	3.6	4.2
17	4	2.7	0.4	1.5	2.7	2.1	1.1	0.8	0.6	0.3	0.3	0.8	1.1	1.2
	8	5.9	0.6	2.9	5.3	4.4	2.2	1.6	1.3	0.7	0.8	1.5	2.2	2.7

(Continued)

Table 5 (Concluded)

Test Wave		Wave Height, ft												
Period sec	Height ft	Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13
						209 deg								
7	8	5.8	0.3	2.3	4.4	5.0	2.4	0.5	0.3	0.3	0.5	1.0	4.6	2.9
	12	9.8	0.5	3.9	7.4	10.2	3.9	0.9	0.6	0.8	1.0	2.8	7.0	6.1
9	8	7.2	0.4	3.8	5.5	6.5	4.7	0.7	0.6	0.7	0.9	1.6	4.6	3.6
	16	13.6	1.0	6.7	10.4	14.3	7.4	1.5	1.4	2.0	2.2	4.2	9.2	9.2
11	6	4.7	0.4	3.1	3.4	3.9	3.9	0.5	0.5	0.6	0.5	0.8	3.3	2.7
	10	7.2	0.7	5.1	5.8	6.9	6.0	0.9	0.9	0.9	1.0	1.6	5.8	4.8
	16	13.3	1.5	8.2	9.2	13.9	8.9	1.9	1.6	2.2	2.4	4.2	9.4	10.3
15	8	4.9	1.1	4.4	3.1	4.8	5.2	0.8	0.5	0.5	0.7	1.4	3.1	3.2
						154 deg								
5	10	5.9	1.9	6.6	7.0	1.8	1.4	1.3	1.0	1.1	0.5	1.0	1.3	1.1
7	8	4.9	1.6	5.9	4.9	2.6	1.3	1.9	1.4	1.2	0.9	1.6	1.4	1.2
	12	8.0	2.3	8.8	8.0	4.3	2.0	2.8	2.2	1.9	1.6	2.4	2.1	1.7
11	10	7.2	2.3	8.4	5.7	8.0	3.6	2.9	2.3	2.7	1.8	2.4	5.0	2.9
15	10	5.4	1.9	5.5	3.8	8.6	3.6	2.6	1.8	1.8	1.6	2.6	4.4	[illegible]

Table 6

Additional Design Wave Information for Plan 1

Test Wave		Wave Height, ft						
Period sec	Height ft	Gage 14	Gage 15	Gage 16	Gage 17	Gage 18	Gage 19	Gage 20
				231 deg				
5	4	0.1	0.1	0.1	0.1	0.7	0.2	1.1
	10	0.1	0.2	0.3	0.6	2.6	0.8	3.1
7	4	0.1	0.1	0.2	0.3	1.3	0.4	1.4
	10	0.2	0.3	0.5	0.7	4.1	1.2	3.9
	14	0.2	0.4	0.7	1.2	5.9	1.8	4.6
9	4	0.1	0.2	0.4	0.5	2.7	0.8	2.0
	10	0.3	0.5	0.8	1.2	6.3	1.9	5.2
	14	0.4	0.6	1.1	1.7	7.7	2.5	6.9
11	4	0.2	0.3	0.7	0.6	2.6	1.0	3.1
	8	0.3	0.5	1.2	1.2	5.2	1.9	5.9
	12	0.5	0.6	1.6	1.5	6.8	2.6	7.5
13	4	0.2	0.3	0.7	0.7	3.5	1.0	2.1
	8	0.3	0.4	1.0	1.0	5.3	1.7	3.2
	12	0.5	0.6	1.4	1.6	8.3	2.8	4.6
15	6	0.3	0.3	0.8	0.9	5.1	1.6	2.5
	12	0.6	0.6	1.4	1.6	9.2	3.0	4.5
17	4	0.2	0.3	0.7	0.6	3.6	1.2	1.5
	8	0.5	0.6	1.4	1.3	7.3	2.5	3.3
				209 deg				
7	8	0.4	0.9	0.9	2.5	6.0	1.6	2.6
	12	0.5	1.4	2.7	3.9	9.8	3.2	4.3
9	8	0.5	0.8	1.5	3.1	7.6	2.3	5.3
	16	1.3	2.0	3.4	6.4	15.3	5.5	11.8
11	6	0.5	0.6	1.2	2.3	4.3	1.3	3.9
	10	0.8	1.0	1.9	4.1	7.4	2.3	7.0
	16	1.7	2.2	3.5	7.3	13.1	5.0	12.7
15	8	0.6	0.6	1.6	3.3	5.0	1.8	3.9

(Continued)

Table 6 (Concluded)

Test Wave		Wave Height, ft						
Period sec	Height ft	Gage 14	Gage 15	Gage 16	Gage 17	Gage 18	Gage 19	Gage 20
				154 deg				
5	10	1.1	2.6	3.7	6.4	3.9	1.8	1.0
7	8	1.3	2.5	3.7	5.0	5.4	3.0	1.2
	12	2.1	4.1	6.4	8.5	9.2	4.8	1.9
11	10	2.1	3.4	7.6	6.4	12.1	3.5	3.0
15	10	1.9	2.6	6.5	7.1	12.7	4.7	3.6

Table 7

Wave Heights for Plans 2-4 for Test Waves

from 209 deg

Test Wave		Wave Height, ft												
Period sec	Height ft	Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13
							Plan 2							
9	8	6.7	0.3	3.1	5.2	5.6	3.9	0.6	0.5	0.9	0.9	1.6	4.5	2.8
11	6	4.1	0.3	2.6	3.1	2.9	3.3	0.5	0.5	0.6	0.5	0.7	2.8	2.2
	16	13.2	1.4	7.9	8.9	13.5	8.6	1.6	1.6	2.1	2.1	3.9	10.3	10.0
							Plan 3							
9	8	7.2	0.4	3.2	5.2	6.5	4.2	0.7	0.6	0.7	0.7	1.6	5.1	3.6
11	6	4.4	0.3	2.6	3.1	3.3	3.3	0.6	0.5	0.4	0.4	0.7	2.9	2.4
	16	12.8	1.3	7.5	8.6	11.7	8.3	1.6	1.6	2.0	2.1	3.7	8.9	8.8
							Plan 4							
9	8	7.0	0.4	3.1	5.6	5.5	4.0	0.8	0.6	0.7	0.8	1.7	4.7	2.8
11	6	4.2	0.3	2.5	3.1	3.3	3.4	0.5	0.5	0.5	0.4	0.8	3.0	2.3
	16	12.7	1.4	7.3	8.5	12.0	8.1	1.6	1.5	2.0	2.0	3.5	9.1	8.5

Table 8

Wave Heights for Plans 5 and 6 for Test Waves from 209 and 154 deg

Test Wave		Wave Height, ft												
Period sec	Height ft	Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13
						Plan 5, 209 deg								
7	8	6.4	0.2	2.6	4.6	5.9	1.3	0.5	0.4	0.4	0.5	1.0	5.3	3.7
	12	10.7	0.4	4.5	8.0	10.3	2.1	1.0	0.8	0.9	1.2	2.3	7.6	6.1
9	8	7.7	0.4	3.9	6.4	6.0	1.8	0.6	0.6	0.9	0.8	1.0	4.7	3.6
	16	14.5	0.8	6.8	11.7	14.0	4.0	1.6	1.5	2.5	2.0	3.9	9.2	8.4
11	6	4.9	0.3	3.1	3.5	4.0	1.1	0.5	0.5	0.5	0.4	0.5	2.9	2.8
	10	8.1	0.5	5.3	5.9	8.2	2.4	1.0	0.9	1.0	0.8	1.1	5.8	5.0
	16	13.2	1.3	8.3	10.0	13.8	5.5	2.1	1.9	2.0	1.9	3.0	9.4	10.1
15	8	4.9	1.0	4.7	3.4	4.7	1.8	0.8	0.6	0.5	0.7	0.8	2.5	2.7
						Plan 5, 154 deg								
5	10	7.8	1.8	6.9	7.0	3.0	0.4	0.6	0.4	0.3	0.7	0.9	0.9	0.6
7	8	6.5	1.9	6.2	5.7	4.2	0.6	0.7	0.6	0.6	0.8	1.4	1.4	0.8
	12	11.2	2.6	9.6	9.2	6.1	1.0	1.0	1.1	1.1	1.3	2.0	1.8	1.1
11	10	9.7	2.7	9.0	6.9	8.4	2.3	1.6	1.5	1.7	1.4	1.7	4.7	3.0
15	10	6.7	2.3	5.5	4.4	8.3	2.5	1.7	1.4	1.2	1.6	1.7	3.7	3.2

(Continued)

Table 8 (Concluded)

Test Wave		Wave Height, ft												
Period sec	Height ft	Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13
						Plan 6, 209 deg								
7	8	6.3	0.2	2.2	4.4	6.1	1.3	0.5	0.3	0.4	0.6	1.1	4.9	3.1
	12	9.7	0.3	3.6	7.5	9.2	2.3	0.9	0.4	0.8	1.0	2.3	6.6	5.3
9	8	7.2	0.3	3.3	5.5	6.3	1.8	0.7	0.4	0.9	0.8	1.3	4.3	2.9
	16	13.5	0.7	6.5	10.4	14.2	4.1	1.5	1.1	2.2	1.8	3.4	7.9	6.8
11	6	4.3	0.3	2.4	3.1	4.1	1.2	0.6	0.3	0.5	0.4	0.6	2.4	2.4
	10	6.8	0.5	4.8	5.8	6.7	2.4	0.9	0.6	0.9	0.7	1.1	4.9	3.7
	16	12.2	1.2	7.8	8.7	13.2	5.4	1.9	1.3	2.0	1.8	2.8	8.6	8.5
15	8	4.5	0.9	4.1	3.0	4.4	1.9	0.8	0.6	0.6	0.7	1.0	2.3	2.4

Table 9

Wave Heights for Plans 7 and 8 for Test Waves

from 209 deg

Test Wave		Wave Height, ft												
Period sec	Height ft	Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13
							Plan 7							
7	8	5.6	0.2	2.3	4.0	5.2	2.3	0.6	0.4	0.4	0.6	1.4	4.0	2.8
	12	9.3	0.4	3.7	7.3	9.1	3.6	1.1	0.6	0.8	1.3	2.7	6.2	5.4
9	8	7.2	0.3	3.3	5.4	6.3	4.4	0.8	0.6	1.0	0.9	1.8	4.3	3.1
	16	13.7	0.8	6.1	10.2	13.9	6.4	1.7	1.2	2.4	2.2	4.1	8.4	7.8
11	6	4.3	0.4	2.6	3.1	3.5	3.7	0.7	0.5	0.6	0.5	0.9	2.8	2.6
	10	7.1	0.6	4.5	5.1	7.0	6.1	1.2	0.8	1.0	1.0	1.6	5.6	4.6
	16	13.4	1.4	7.7	8.5	13.3	9.4	2.1	1.7	2.2	2.3	3.8	8.7	9.9
15	8	4.8	1.0	4.4	3.2	3.9	5.4	0.9	0.6	0.6	0.7	1.2	2.6	3.2
							Plan 8							
7	8	5.6	0.3	2.4	3.8	5.3	2.5	0.5	0.3	0.3	0.4	0.9	4.0	3.3
	12	10.2	0.4	3.9	7.9	10.8	4.0	1.1	0.6	0.8	1.2	2.7	6.7	5.8
9	8	7.5	0.4	3.6	5.6	7.8	4.8	0.9	0.6	0.9	0.9	1.6	4.5	4.3
	16	14.4	0.9	6.7	9.6	15.3	7.2	1.8	1.2	2.3	2.1	4.2	8.5	8.6
11	6	4.5	0.4	2.7	3.2	3.9	3.6	0.7	0.5	0.5	0.4	0.7	2.7	2.7
	10	7.2	0.6	4.6	5.5	7.1	6.1	1.2	0.7	1.0	1.0	1.4	5.3	4.5
	16	12.7	1.3	7.8	8.7	13.6	9.2	2.2	1.5	2.0	2.1	3.4	8.0	10.0
15	8	4.7	1.0	4.3	3.2	4.0	5.5	0.8	0.5	0.5	0.6	1.1	2.5	3.2

Table 10

Wave Heights for Plans 9-13 for Test Waves from 209 deg

Test Wave		Wave Height, ft												
Period sec	Height ft	Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13
							Plan 9							
7	8	5.5	0.2	1.1	2.7	5.9	2.7	0.6	0.3	0.4	0.5	1.1	4.6	3.2
	12	8.6	0.3	2.0	4.3	9.3	3.6	1.0	0.7	0.8	1.1	2.9	6.3	4.4
9	8	6.9	0.3	2.1	4.2	7.2	5.1	0.8	0.6	0.8	0.8	1.6	5.1	3.7
	16	10.7	0.8	3.4	6.1	13.4	6.7	1.7	1.3	2.1	2.3	4.1	7.5	6.9
11	6	4.2	0.4	2.7	2.5	4.2	4.1	0.7	0.5	0.5	0.4	0.8	3.6	3.0
	10	5.9	0.5	4.0	2.9	6.9	5.6	0.9	0.7	0.8	0.9	1.3	5.3	4.6
	16	8.7	1.3	5.8	5.8	11.7	8.4	2.0	1.7	2.1	2.4	3.7	8.0	8.1
15	8	4.9	1.2	4.2	3.3	5.6	6.3	1.2	0.7	0.8	1.0	1.9	3.8	3.6
							Plan 10							
7	8	4.0	0.2	1.3	2.8	5.5	2.1	0.5	0.3	0.4	0.5	1.2	3.8	2.3
	12	5.0	0.3	2.0	3.3	6.8	3.9	0.7	0.5	0.6	1.0	2.5	5.1	3.7
9	8	5.1	0.3	1.6	3.3	6.4	4.5	0.7	0.4	0.7	0.7	1.5	4.1	2.8
	16	7.7	0.8	3.3	5.0	10.6	6.5	1.6	1.2	1.8	2.0	3.4	6.4	5.7
11	6	3.3	0.3	2.4	2.1	3.1	3.8	0.6	0.4	0.4	0.4	0.7	2.7	2.3
	10	4.2	0.6	3.4	2.4	4.7	5.4	0.9	0.7	0.7	0.9	1.2	4.2	3.9
	16	6.4	1.3	4.9	5.1	10.1	8.2	1.9	1.5	1.8	2.2	3.4	6.9	7.0
15	8	3.7	1.0	3.3	2.3	4.5	5.3	0.8	0.5	0.6	0.7	1.4	2.7	2.8

(Continued)

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Table 10 (Continued)

Test Wave		Wave Height, ft												
Period sec	Height ft	Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13
						Plan 11								
7	8	2.8	0.2	1.3	2.5	4.1	2.5	0.5	0.3	0.3	0.4	1.2	2.8	1.9
	12	4.2	0.3	2.0	3.4	6.7	3.6	0.8	0.5	0.6	1.0	2.1	4.7	3.2
9	8	3.7	0.4	1.9	2.6	5.1	4.9	0.7	0.5	0.6	0.7	1.6	3.2	2.7
	16	5.6	0.8	3.6	4.8	9.6	6.9	1.6	1.1	1.6	2.0	3.3	5.5	5.3
11	6	2.3	0.4	1.7	1.9	2.6	4.0	0.5	0.4	0.3	0.3	0.6	2.4	2.1
	10	3.0	0.7	2.8	2.2	4.2	5.5	1.0	0.7	0.7	0.9	1.1	4.0	3.6
	16	5.4	1.3	4.4	5.0	8.2	8.1	1.8	1.3	1.7	2.2	3.3	5.6	7.1
15	8	3.2	0.9	2.9	2.3	4.2	5.0	0.8	0.5	0.4	0.7	1.5	2.4	2.8
						Plan 12								
7	8	2.5	0.2	1.0	1.3	3.9	2.2	0.3	0.2	0.2	0.3	0.8	1.9	0.9
	12	3.7	0.3	1.7	2.2	5.3	3.4	0.7	0.5	0.5	0.8	1.8	4.1	2.1
9	8	3.3	0.3	2.1	1.9	4.2	4.6	0.6	0.4	0.5	0.6	1.2	2.5	1.9
	16	5.0	0.8	4.0	4.1	7.1	6.0	1.5	1.1	1.5	1.9	3.0	4.4	4.5
11	6	2.2	0.3	1.8	1.5	2.6	4.0	0.5	0.4	0.4	0.4	0.7	2.4	2.1
	10	3.4	0.6	2.9	2.6	4.1	5.	0.8	0.7	0.7	0.8	1.2	3.9	3.5
	16	5.6	1.3	4.7	5.1	6.7	7.9	1.8	1.4	1.5	2.0	3.1	5.1	6.8
15	8	3.1	0.8	2.5	2.2	4.1	5.1	0.7	0.6	0.4	0.5	1.2	2.3	3.0

(Continued)

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Table 10 (Concluded)

Test Wave		Wave Height, ft												
Period sec	Height ft	Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13
							Plan 13							
7	8	1.6	0.2	0.9	1.1	4.0	2.4	0.4	0.3	0.3	0.5	1.2	2.4	1.7
	12	2.8	0.3	1.9	1.6	5.1	3.3	0.8	0.5	0.6	0.9	1.9	3.7	2.3
9	8	2.6	0.3	1.9	1.5	4.2	4.6	0.8	0.5	0.8	0.8	1.3	2.7	2.2
	16	5.1	0.9	3.5	3.9	7.3	6.5	1.7	1.1	1.8	2.2	3.2	4.7	4.6
11	8	2.3	0.4	1.9	1.6	2.7	4.1	0.6	0.4	0.6	0.5	0.7	2.4	2.1
	10	3.4	0.7	3.3	2.6	4.3	6.1	0.9	0.7	0.8	0.8	1.2	4.1	3.7
	16	5.3	1.4	5.2	4.7	6.5	8.0	2.0	1.5	1.7	2.4	3.2	5.5	6.8
15	8	3.2	1.0	2.7	2.5	4.4	5.2	0.8	0.5	0.5	0.6	1.3	2.4	3.1

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Table 11

Wave Heights for Plans 14-18 for Test Waves

from 209 deg

Test Wave		Wave Height, ft												
Period sec	Height ft	Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13
							Plan 14							
7	8	1.8	0.2	1.0	1.0	2.0	2.2	0.4	0.3	0.3	0.4	0.9	1.5	1.3
	12	2.8	0.3	2.0	1.7	4.1	3.3	0.7	0.5	0.5	0.8	1.5	3.0	2.8
9	8	2.4	0.4	2.0	1.3	3.5	4.2	0.6	0.5	0.7	0.7	1.0	2.3	2.3
	16	4.8	1.0	3.5	3.6	5.9	6.0	1.4	1.1	1.5	1.9	2.8	3.9	4.2
11	6	2.2	0.4	2.0	1.5	2.5	4.1	0.5	0.4	0.5	0.5	0.7	2.2	2.2
	10	3.2	0.7	3.3	2.4	4.1	6.5	0.8	0.7	0.8	0.9	1.2	3.6	3.7
	16	5.3	1.4	5.4	4.7	5.8	8.9	2.0	1.5	1.5	2.6	2.8	5.3	6.0
15	8	3.0	0.9	2.8	2.7	4.0	5.6	0.8	0.6	0.6	0.8	1.4	2.2	3.2
							Plan 15							
7	8	2.6	0.2	1.1	1.7	2.4	2.1	0.4	0.3	0.3	0.5	1.0	2.0	1.3
	12	3.3	0.3	1.9	1.9	5.3	3.1	0.7	0.4	0.5	0.8	1.4	3.7	2.8
9	8	3.4	0.3	2.2	2.1	2.9	4.3	0.6	0.4	0.5	0.6	1.0	2.2	2.1
	16	4.7	0.7	3.8	3.7	6.3	6.1	1.4	1.0	1.4	1.9	2.7	3.8	4.1
11	6	2.5	0.4	1.7	1.5	2.1	4.1	0.5	0.4	0.4	0.4	0.6	2.1	2.1
	10	3.7	0.6	2.5	2.5	3.9	5.7	0.8	0.6	0.7	0.8	1.2	3.4	3.7
	16	5.9	1.2	4.7	5.0	6.0	7.8	1.8	1.2	1.4	2.4	3.0	4.4	6.2
15	8	3.3	0.9	2.5	2.5	3.8	5.5	0.7	0.6	0.4	0.6	1.2	2.4	3.1

(Continued)

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Table 11 (Continued)

Test Wave Period sec	Test Wave Height ft	Wave Height, ft Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13
							Plan 16							
7	8	2.5	0.2	1.2	2.1	3.6	2.3	0.5	0.3	0.3	0.5	1.2	2.0	1.2
	12	4.0	0.3	2.0	3.2	5.3	3.5	0.7	0.5	0.5	0.7	1.6	3.6	2.1
9	8	3.3	0.3	1.7	2.2	4.1	4.4	0.7	0.4	0.5	0.8	1.2	2.4	2.1
	16	5.3	0.7	3.5	4.7	8.1	6.7	1.5	1.1	1.5	1.9	3.2	4.6	4.5
11	6	2.3	0.4	1.8	1.7	2.1	4.0	0.6	0.4	0.3	0.4	0.7	2.1	2.1
	10	3.3	0.6	2.8	2.3	4.0	5.6	0.8	0.6	0.6	0.7	1.2	3.6	3.5
	16	5.5	1.2	4.3	4.8	7.1	8.0	1.8	1.3	1.5	2.3	3.2	5.0	6.4
15	8	3.4	0.9	2.8	2.2	3.5	5.4	0.7	0.5	0.4	0.6	1.2	2.4	3.0
							Plan 17							
7	8	4.0	0.2	1.1	2.8	4.4	2.4	0.6	0.3	0.3	0.4	1.1	3.0	2.3
	12	5.7	0.3	2.1	3.9	7.5	3.7	0.8	0.5	0.6	1.0	2.2	4.8	3.6
9	8	4.7	0.3	1.5	2.9	5.6	4.5	0.7	0.5	0.7	0.8	1.6	3.5	2.7
	16	6.8	1.2	4.9	5.4	9.9	8.1	2.0	1.5	1.7	2.3	3.7	6.6	6.9
11	6	2.7	0.3	2.1	1.6	2.8	3.8	0.5	0.4	0.4	0.3	0.7	2.3	2.2
	10	4.2	0.5	3.2	2.5	6.1	5.7	0.9	0.7	0.7	0.8	1.5	4.4	4.1
	16	7.0	1.2	4.9	5.5	10.0	8.8	2.0	1.5	1.7	2.3	3.7	6.7	7.2
15	8	3.4	0.8	3.1	2.1	3.3	5.4	0.7	0.5	0.4	0.5	1.2	2.4	2.8

(Continued)

Table 11 (Concluded)

Test Wave		Wave Height, ft												
Period sec	Height ft	Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13
							Plan 18							
7	8	5.7	0.2	1.0	3.0	5.7	2.1	0.6	0.4	0.4	0.5	1.3	3.8	2.6
	12	9.7	0.5	2.2	4.7	9.8	4.3	1.0	0.7	0.8	1.4	2.8	6.2	5.4
9	8	7.0	0.3	2.0	3.8	6.7	4.3	0.8	0.5	0.8	0.9	1.7	4.2	3.2
	16	11.8	0.9	3.5	6.6	12.9	7.2	1.7	1.3	2.0	2.3	4.0	7.7	6.6
11	6	4.0	0.3	2.5	2.1	3.6	3.9	0.6	0.4	0.5	0.5	0.9	2.9	2.6
	10	6.6	0.6	4.4	3.2	7.1	6.0	1.1	0.8	0.9	0.9	1.6	5.2	4.6
	16	9.6	1.3	6.0	6.0	11.7	8.9	2.1	1.6	1.9	2.5	3.7	7.8	8.1
15	8	4.4	1.0	3.7	2.3	4.1	5.4	0.8	0.5	0.5	0.7	1.3	2.7	3.0

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Table 12

Wave Heights for Plans 9 and 18 for Test Waves

from 231 deg

Test Wave		Wave Height, ft												
Period sec	Height ft	Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13
							Plan 9							
7	14	5.4	0.2	1.7	2.3	4.7	2.1	0.5	0.4	0.3	0.4	0.8	2.7	3.5
9	14	5.5	0.3	1.9	3.2	4.7	2.1	0.7	0.8	0.8	0.7	1.1	2.9	4.0
11	12	4.9	0.3	2.6	4.5	3.9	2.1	0.8	0.9	0.7	0.6	0.8	2.8	4.2
13	12	5.4	0.5	2.5	4.7	4.3	2.0	0.8	0.9	0.6	0.7	0.8	2.8	3.7
15	12	5.3	0.5	2.1	4.4	4.7	2.1	0.9	1.0	0.7	0.7	1.1	2.2	2.8
17	8	4.3	0.5	1.8	4.8	3.4	1.7	1.1	1.1	0.6	0.6	1.1	1.6	1.8
							Plan 18							
7	14	5.3	0.2	1.6	2.0	4.7	1.8	0.4	0.4	0.3	0.4	0.7	2.5	3.5
9	14	5.3	0.3	1.9	3.4	4.2	1.7	0.7	0.7	0.8	0.7	1.1	2.5	3.0
11	12	4.9	0.4	2.4	4.0	3.5	1.8	0.8	0.8	0.8	0.6	0.8	2.7	3.8
13	12	5.4	0.5	2.7	4.7	4.2	1.9	0.8	0.9	0.5	0.6	0.8	2.6	3.3
15	12	5.5	0.5	2.3	4.5	4.8	2.0	1.0	1.0	0.7	0.6	1.1	2.3	2.8
17	8	4.2	0.5	1.7	4.8	3.3	1.6	1.1	1.1	0.4	0.4	1.0	1.4	1.6

Table 13

Wave Heights for Plan 19 for Test Waves from 209 deg

Test Wave		Wave Height, ft												
Period sec	Height ft	Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13
7	8	5.9	0.3	2.4	4.3	6.1	2.7	1.6	1.7	2.7	1.9	2.7	5.4	3.4
	12	9.4	0.5	4.0	7.1	10.2	4.3	2.4	2.7	3.5	2.3	4.7	7.2	6.6
9	8	7.1	0.3	3.5	5.5	7.2	4.8	2.0	2.3	3.1	3.0	3.4	5.2	3.4
	16	14.5	0.9	6.9	10.1	15.3	7.1	5.0	5.0	5.6	5.9	9.0	9.4	8.0
11	6	4.4	0.3	2.7	3.3	4.3	3.7	1.2	1.3	1.9	2.0	1.8	3.5	2.6
	10	7.5	0.6	5.3	5.5	8.4	6.3	2.0	2.2	3.0	3.0	3.4	6.2	5.3
	16	14.0	1.4	8.0	9.4	14.5	9.5	4.2	4.4	5.8	6.2	8.0	9.3	11.8
15	8	4.8	0.9	4.3	3.0	5.3	5.2	1.9	1.6	2.0	2.3	2.7	3.1	3.3

Table 14

Wave Heights for Plans 20 and 21 for Test Waves

from 209 deg

Test Wave		Wave Height, ft												
Period sec	Height ft	Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13
							Plan 20							
7	8	6.0	0.2	1.8	3.9	5.3	2.0	0.5	0.4	0.4	0.6	0.9	3.6	3.1
	12	9.3	0.3	3.6	6.9	9.1	3.1	1.0	0.6	0.7	0.9	1.9	6.0	4.5
9	8	6.8	0.3	3.1	5.5	6.4	4.1	0.9	0.5	0.8	0.8	1.1	3.3	3.1
	16	13.3	0.8	5.8	8.2	14.0	5.6	1.7	1.2	1.8	1.7	2.6	7.1	6.7
11	6	4.0	0.3	2.4	2.5	3.5	3.4	0.6	0.4	0.4	0.4	0.5	2.4	2.2
	10	7.3	0.5	4.3	4.5	6.3	5.4	1.0	0.7	0.8	0.8	1.1	4.1	4.3
	16	11.7	1.3	7.3	7.0	12.5	7.7	1.9	1.6	1.8	1.7	2.6	6.8	8.2
15	8	4.3	0.9	3.5	2.2	3.8	4.5	0.7	0.5	0.5	0.6	1.2	2.4	3.2
							Plan 21							
7	8	5.7	0.2	1.9	3.5	4.8	2.1	0.5	0.4	0.5	0.5	0.9	3.6	3.2
	12	8.6	0.4	3.6	6.7	7.9	3.3	1.0	0.6	0.8	0.9	1.7	5.2	5.2
9	8	6.8	0.4	3.3	5.4	5.4	3.6	0.8	0.6	0.8	0.9	1.2	4.0	3.1
	16	13.3	0.8	5.7	8.1	13.0	5.5	1.5	1.1	1.7	1.6	2.5	6.6	7.0
11	6	4.0	0.3	2.7	2.9	3.2	3.0	0.5	0.4	0.4	0.4	0.6	2.6	2.3
	10	6.4	0.5	4.5	4.8	6.0	4.9	0.9	0.6	0.8	0.8	1.2	4.4	4.5
	16	11.6	1.2	7.3	7.3	11.6	7.4	1.8	1.4	1.6	1.9	2.4	6.6	8.3
15	8	4.2	0.9	3.7	2.5	3.8	4.5	0.7	0.5	0.6	0.6	1.1	2.7	3.2

Table 15

Wave Heights for Plan 20 for Test Waves

from 231 and 154 deg

Test Wave		Wave Height, ft												
Period sec	Height ft	Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13
							231 deg							
5	4	2.8	0.1	0.3	0.6	1.2	1.2	0.2	0.1	0.1	0.1	0.1	0.3	0.6
	10	7.4	0.2	1.0	2.1	3.9	2.9	0.5	0.2	0.2	0.3	0.3	1.4	3.2
7	4	3.4	0.1	0.4	0.8	1.4	1.4	0.3	0.2	0.2	0.2	0.2	0.5	0.9
	10	9.8	0.2	1.5	3.1	5.5	3.6	0.7	0.4	0.3	0.4	0.6	2.0	3.7
	14	12.7	0.3	2.4	4.5	7.9	4.3	0.9	0.6	0.6	0.8	1.0	3.7	5.1
9	4	4.8	0.2	0.9	2.0	2.7	1.6	0.5	0.4	0.3	0.4	0.5	1.2	1.7
	10	11.3	0.3	1.9	4.8	6.8	3.7	1.0	0.8	0.5	0.9	0.9	2.9	4.2
	14	14.3	0.4	2.2	6.1	9.6	4.7	1.4	0.8	0.6	0.9	0.9	3.9	5.8
11	4	4.6	0.2	0.8	2.5	2.6	1.7	0.5	0.3	0.2	0.3	0.3	1.4	2.1
	8	9.7	0.3	1.7	5.3	5.8	3.4	0.9	0.6	0.7	0.6	0.8	3.3	4.7
	12	13.3	0.5	2.6	7.0	7.7	4.6	1.4	0.9	0.6	0.9	0.9	4.4	6.6
13	4	4.9	0.2	1.3	3.1	3.2	1.6	0.4	0.3	0.3	0.3	0.4	1.7	2.3
	8	7.8	0.4	2.1	4.6	5.1	2.4	0.7	0.6	0.8	0.6	0.7	2.8	3.7
	12	11.6	0.6	3.4	6.4	7.7	3.4	1.1	0.8	1.0	1.1	0.9	4.0	5.5
15	6	5.7	0.4	1.7	3.3	4.1	2.0	0.5	0.4	0.4	0.4	0.7	1.8	2.4
	12	10.7	0.7	3.3	5.7	7.7	3.4	1.1	0.8	0.6	0.9	1.1	3.4	4.2
17	4	3.4	0.3	1.5	2.7	2.2	1.1	0.5	0.4	0.3	0.3	0.6	1.0	1.3
	8	7.2	0.6	2.8	5.4	4.5	2.2	1.2	0.8	0.5	0.6	0.9	1.9	2.7

(Continued)

Table 15 (Concluded)

Test Wave		Wave Height, ft												
Period sec	Height ft	Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13
							154 deg							
5	10	7.4	2.0	7.4	6.8	2.8	1.4	1.1	1.2	1.4	0.8	0.9	1.6	1.3
7	8	6.7	1.8	6.8	4.7	3.3	1.6	1.1	1.1	1.2	0.6	1.1	1.7	1.4
	12	10.8	2.6	9.4	8.3	4.8	2.4	1.7	1.6	1.8	0.9	1.6	2.7	2.0
11	10	9.5	2.5	9.1	5.3	8.7	3.3	2.3	1.9	2.0	1.7	1.9	5.1	3.0
15	10	7.0	1.9	5.7	3.2	9.0	3.1	1.8	1.5	1.5	1.1	2.5	4.2	3.5

Table 16

Wave Heights for Plans 22 and 23 for Test Waves from 209 deg

Test Wave Period sec	Test Wave Height ft	Wave Height, ft Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13
							Plan 22							
7	8	4.4	0.2	1.9	3.2	3.8	1.8	0.4	0.4	0.5	0.4	0.9	3.3	2.4
	12	9.2	0.4	4.4	7.7	7.7	4.1	1.2	1.0	1.3	1.4	3.5	7.7	3.6
9	8	6.8	0.4	3.5	5.0	5.4	4.7	0.8	0.7	1.1	1.0	1.6	5.1	3.1
	16	14.3	0.9	7.0	9.4	15.3	7.8	2.1	2.0	2.8	2.7	4.8	10.7	9.6
11	6	4.1	0.3	2.7	2.6	3.1	3.6	0.5	0.4	0.6	0.5	0.7	2.9	2.7
	10	7.3	0.5	5.1	4.7	6.7	6.3	1.0	0.9	1.1	1.1	1.6	6.8	5.0
	16	13.4	1.4	8.4	7.7	13.3	9.5	2.3	2.0	2.6	2.9	3.9	11.3	9.9
15	8	5.1	0.9	4.1	3.1	4.3	5.7	0.9	0.8	0.8	0.8	1.6	3.8	3.2
							Plan 23							
7	8	4.4	0.7	1.7	2.3	3.6	2.1	0.4	0.4	0.5	0.4	0.8	4.0	2.7
	12	8.7	0.7	3.5	6.5	6.6	3.8	0.9	0.9	1.2	1.1	2.9	7.6	4.9
9	8	6.0	0.3	3.2	4.6	3.9	4.2	0.7	0.6	1.1	0.9	1.6	4.9	2.8
	16	13.4	0.7	6.5	8.3	10.7	6.8	1.9	1.8	2.7	2.5	4.5	9.5	8.0
11	6	3.6	0.2	2.4	2.4	2.3	3.3	0.4	0.4	0.6	0.5	0.7	3.3	2.2
	10	6.4	0.5	4.8	4.7	4.7	5.5	1.0	0.8	1.1	1.2	1.6	6.6	4.6
	16	12.1	1.3	7.5	7.3	9.0	8.1	2.1	1.6	2.1	2.4	3.7	10.5	7.7
15	8	4.4	0.8	4.1	2.8	2.8	4.6	0.8	0.7	0.6	0.6	1.3	3.5	3.7

Table 17

Wave Heights for Plan 22 for Test Waves

from 231 and 154 deg

Test Wave		Wave Height, ft												
Period sec	Height ft	Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13
							231 deg							
5	4	2.6	0.1	0.2	0.5	1.1	1.2	0.2	0.1	0.1	0.1	0.1	0.5	0.6
	10	7.1	0.1	1.1	2.1	3.9	3.3	0.5	0.2	0.2	0.3	0.4	1.9	2.8
7	4	1.6	0.1	0.4	0.5	0.8	0.8	0.7	0.1	0.1	0.1	0.2	0.4	0.5
	10	9.0	0.2	1.4	3.0	5.0	3.4	0.8	0.5	0.5	0.4	0.9	2.8	3.5
	14	12.3	0.3	2.6	4.9	7.4	4.4	1.0	0.7	0.8	0.8	1.4	4.4	4.9
9	4	3.5	0.1	0.8	1.7	2.1	1.3	0.4	0.3	0.4	0.4	0.4	1.5	1.5
	10	11.5	0.3	2.1	5.0	7.2	4.1	1.0	0.8	1.0	0.9	1.2	4.5	5.0
	14	13.9	0.4	2.4	6.0	8.6	4.8	1.4	1.0	1.2	1.1	1.6	5.6	6.6
11	4	3.7	0.1	0.8	2.0	2.3	1.2	0.5	0.4	0.4	0.4	0.4	2.0	2.3
	8	8.7	0.3	1.6	4.3	5.1	2.8	1.0	0.7	0.8	0.7	0.9	4.4	5.1
	12	12.6	0.4	2.5	6.0	7.6	3.9	1.6	1.0	1.1	1.0	1.2	6.4	7.3
13	4	4.3	0.2	1.2	2.7	2.4	1.6	0.5	0.3	0.3	0.3	0.4	2.2	2.2
	8	7.2	0.4	2.0	4.4	4.1	2.5	0.8	0.6	0.6	0.6	0.8	3.8	3.9
	12	11.2	0.5	3.6	6.5	6.8	3.8	1.4	0.9	0.9	1.0	1.1	5.7	6.2
15	6	5.2	0.4	1.6	3.2	3.5	2.1	0.7	0.5	0.4	0.4	0.7	2.3	2.5
	12	10.4	0.6	3.2	5.8	7.0	3.5	1.6	1.1	1.1	1.0	1.4	4.5	4.9
17	4	3.2	0.3	1.2	2.0	2.0	1.5	0.6	0.8	0.3	0.3	0.6	1.3	1.3
	8	7.4	0.6	2.6	4.5	5.0	3.1	1.7	1.3	0.7	0.7	1.5	2.9	3.1

(Continued)

Table 17 (Concluded)

Test Wave		Wave Height, ft												
Period sec	Height ft	Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13
							154 deg							
5	10	8.1	1.9	6.7	5.2	2.1	1.3	1.5	1.3	1.3	0.9	1.1	1.4	0.9
7	8	4.5	1.3	4.4	3.8	1.7	1.0	1.5	1.2	1.3	0.8	1.6	1.3	0.9
	12	9.5	2.9	8.5	7.8	3.3	2.0	3.0	2.3	2.6	1.8	2.7	2.4	1.5
11	10	8.3	2.7	7.7	5.5	6.4	2.5	2.5	2.0	2.8	2.3	2.3	4.2	2.1
15	10	7.0	2.1	6.0	4.1	6.4	2.3	2.3	1.9	2.1	1.6	2.4	3.9	2.7

Table 18

Wave Heights for Plan 24 for Test Waves

from 231, 209, and 154 deg

Test Wave		Wave Height, ft											
Period sec	Height ft	Gage 21	Gage 22	Gage 23	Gage 24	Gage 25	Gage 26	Gage 27	Gage 28	Gage 29	Gage 30	Gage 31	Gage 32
						231 deg							
7	14	0.3	0.1	0.2	0.2	0.1	0.1	0.2	0.1	0.1	0.2	0.1	0.2
9	14	0.3	0.2	0.3	0.3	0.3	0.4	0.4	0.2	0.3	0.3	0.2	0.3
11	12	0.3	0.2	0.4	0.3	0.2	0.3	0.4	0.2	0.3	0.2	0.3	0.3
13	12	0.3	0.2	0.4	0.3	0.2	0.4	0.4	0.2	0.3	0.3	0.3	0.3
15	12	0.5	0.3	0.6	0.5	0.3	0.6	0.6	0.3	0.5	0.4	0.3	0.4
17	8	0.5	0.3	0.4	0.3	0.2	0.3	0.3	0.3	0.3	0.2	0.3	0.3
						209 deg							
7	12	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
9	16	0.6	0.5	0.4	0.5	0.5	0.7	0.7	0.4	0.5	0.5	0.6	0.6
11	10	0.4	0.2	0.3	0.2	0.2	0.3	0.3	0.2	0.3	0.3	0.4	0.4
	16	0.9	0.7	0.7	0.6	0.5	0.9	0.8	0.5	0.7	0.6	0.8	0.9
15	8	0.5	0.2	0.4	0.3	0.2	0.3	0.3	0.2	0.2	0.2	0.3	0.4

(Continued)

Table 18 (Concluded)

Test Wave		Wave Height, ft											
Period sec	Height ft	Gage 21	Gage 22	Gage 23	Gage 24	Gage 25	Gage 26	Gage 27	Gage 28	Gage 29	Gage 30	Gage 31	Gage 32
						154 deg							
5	10	1.5	0.3	0.2	0.2	0.1	0.1	0.2	0.2	0.3	0.1	0.2	1.0
7	8	1.2	0.3	0.2	0.2	0.1	0.2	0.2	0.1	0.2	0.1	0.2	0.6
	12	2.3	0.6	0.4	0.4	0.3	0.4	0.5	0.3	0.5	0.3	0.5	1.4
11	10	1.8	0.6	1.1	0.7	0.6	0.8	0.7	0.6	0.8	0.6	1.7	1.6
15	10	1.7	0.5	1.0	0.6	0.6	0.7	1.0	0.5	0.6	0.6	1.0	1.2

Table 19

Estimate of Average Time (hours per year) Waves Approach Los Angeles Harbor and Exceed Wave Height Criteria

Average Time (hours per year) Waves Approach Los Angeles Harbor from the Various Test Directions		
231 deg	209 deg	154 deg
626.4	8.25	2.1

	Average Time (hours per year) Established Wave Height Criteria will be Exceeded for Various Test Plans and Directions					
	Container Terminal Mooring Area (Gages 7-11), 1.5-ft criterion			Tanker Terminal Mooring Area (Gages 12 and 13) 6.0-ft criterion		
Plan	231 deg	209 deg	154 deg	231 deg	209 deg	154 deg
1	12.75	6.75	1.95	4.35	3.00	0.00
2	*	6.75	*	*	3.00	*
3	*	6.75	*	*	3.00	*
4	*	6.75	*	*	3.00	*
5	*	4.50	1.35	*	3.00	0.00
6	*	4.50	*	*	3.00	*
7	*	6.75	*	*	3.00	*
8	*	6.60	*	*	3.00	*
9	0.00	7.05	*	0.00	3.00	*
10	*	4.50	*	*	0.90	*
11	*	4.50	*	*	0.15	*
12	*	3.45	*	*	0.15	*
13	*	3.45	*	*	0.15	*
14	*	2.70	*	*	0.00	*
15	*	2.70	*	*	0.15	*
16	*	3.30	*	*	0.15	*
17	*	6.60	*	*	0.90	*
18	0.00	6.75	*	0.00	1.95	*
19	*	8.25	*	*	4.65	*
20	0.00	3.00	0.45	2.55	1.65	0.00
21	*	3.00	*	*	1.65	*
22	12.75	7.20	1.95	14.85	3.60	0.00
23	*	6.75	*	*	3.15	*

* Indicates wave-height tests not conducted for these directions.

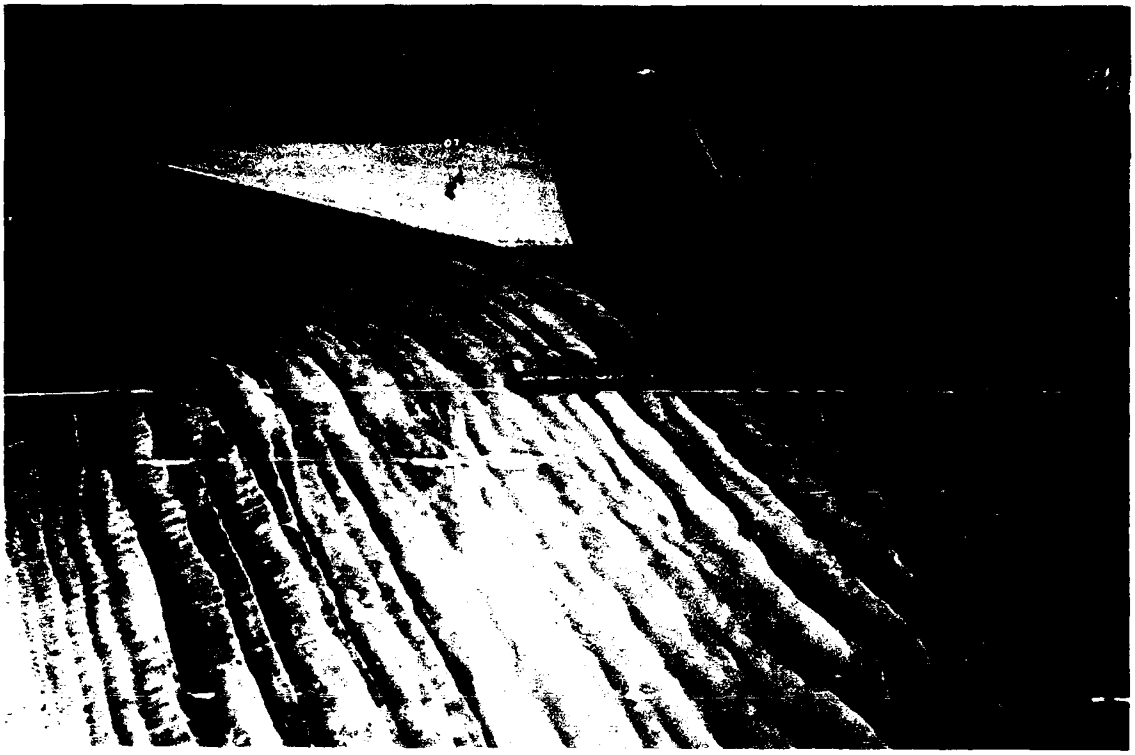


Photo 1. Typical wave patterns for Plan 1; 9-sec, 14-ft waves from 231 deg

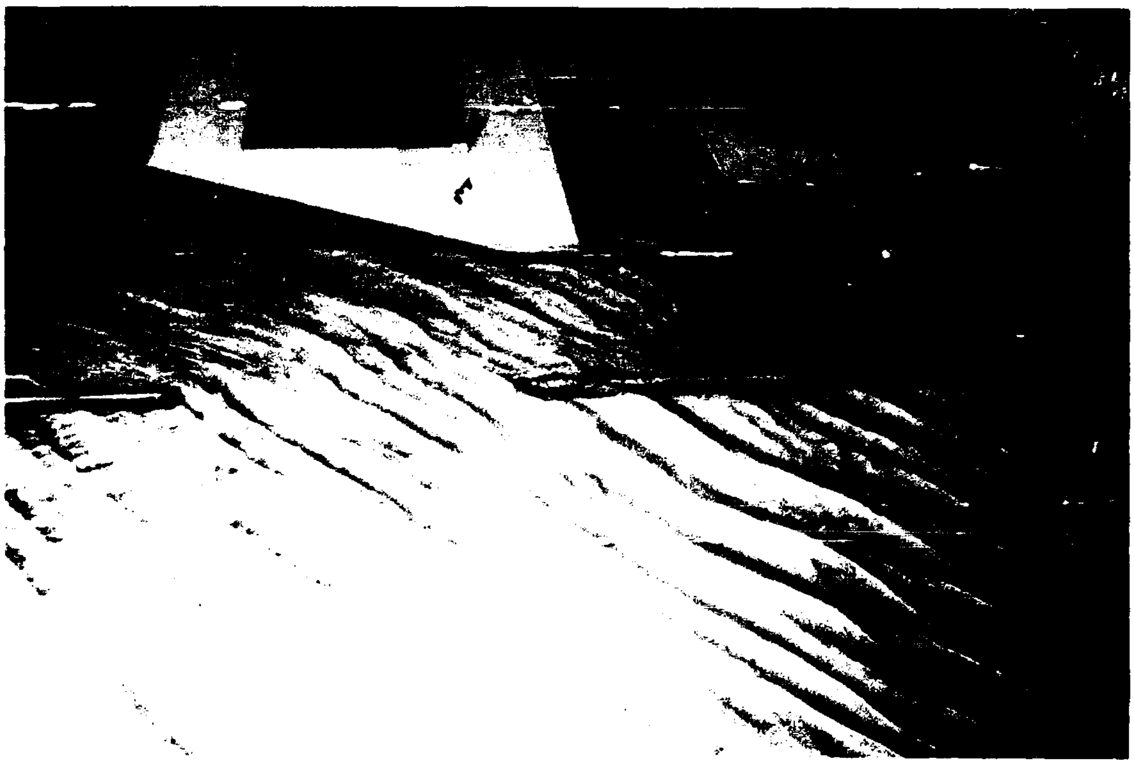


Photo 2. Typical wave patterns for Plan 1; 11-sec, 16-ft waves from 209 deg

Photo 3. Typical wave patterns for Plan 1; 11-sec, 10-ft waves from 154 deg

Photo 4. Typical wave patterns for Plan 2; 11-sec, 16-ft waves from 209 deg

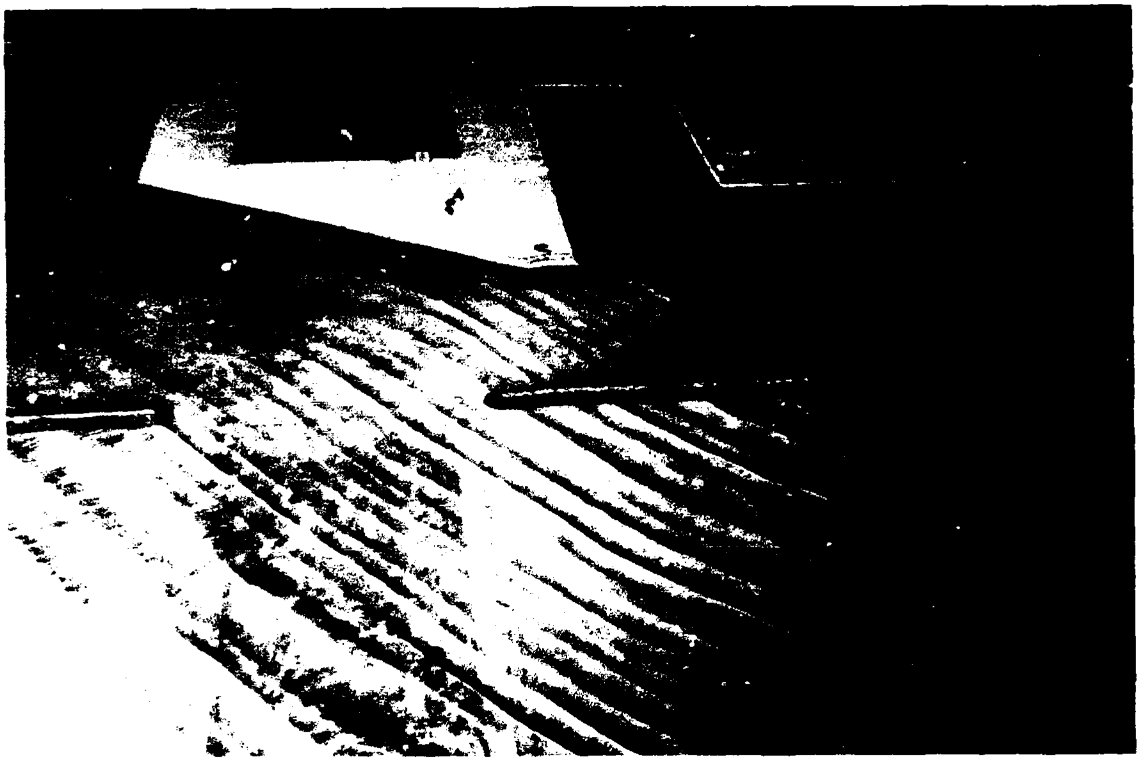


Photo 5. Typical wave patterns for Plan 7; 11-sec, 16-ft waves from 209 deg

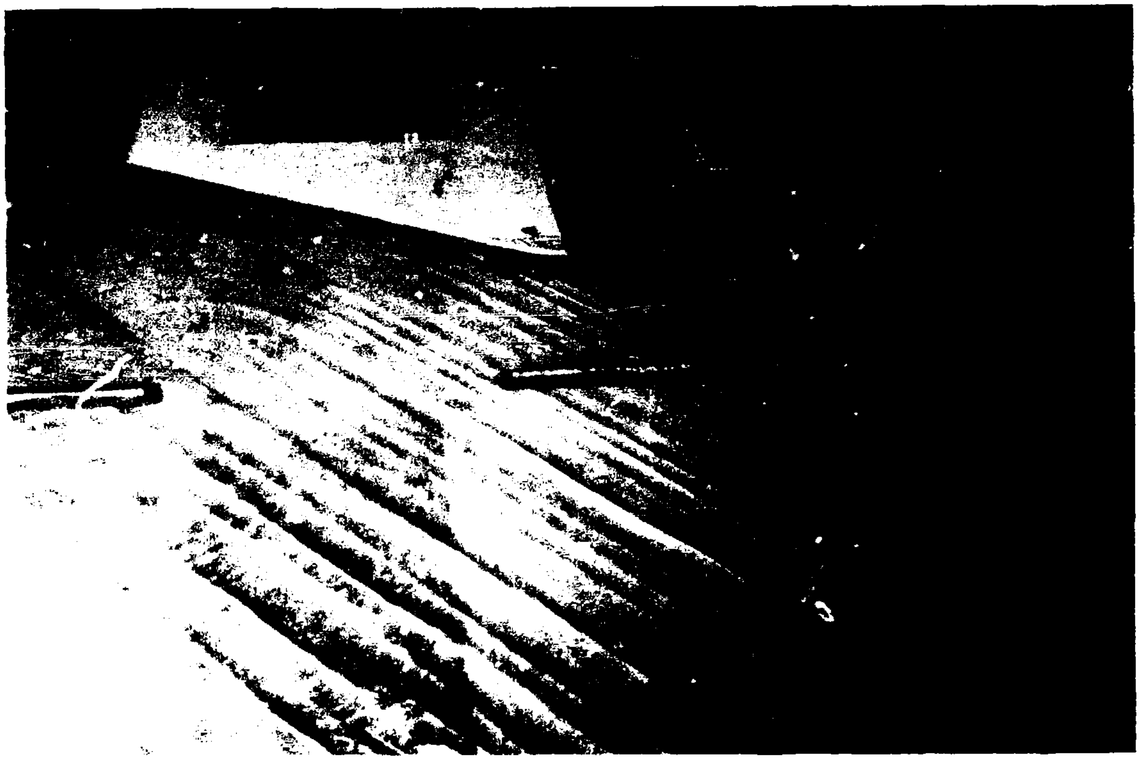


Photo 6. Typical wave patterns for Plan 8; 11-sec, 16-ft waves from 209 deg

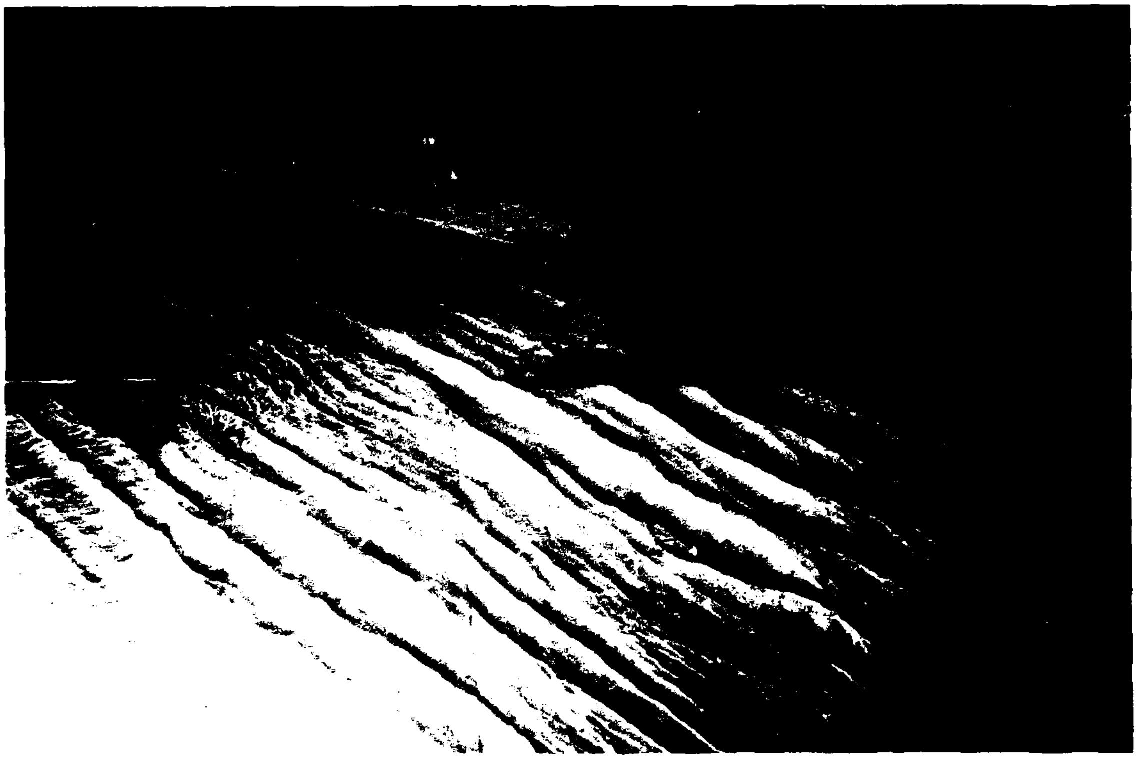


Photo 7. Typical wave patterns for Plan 9; 11-sec, 16-ft waves from 209 deg

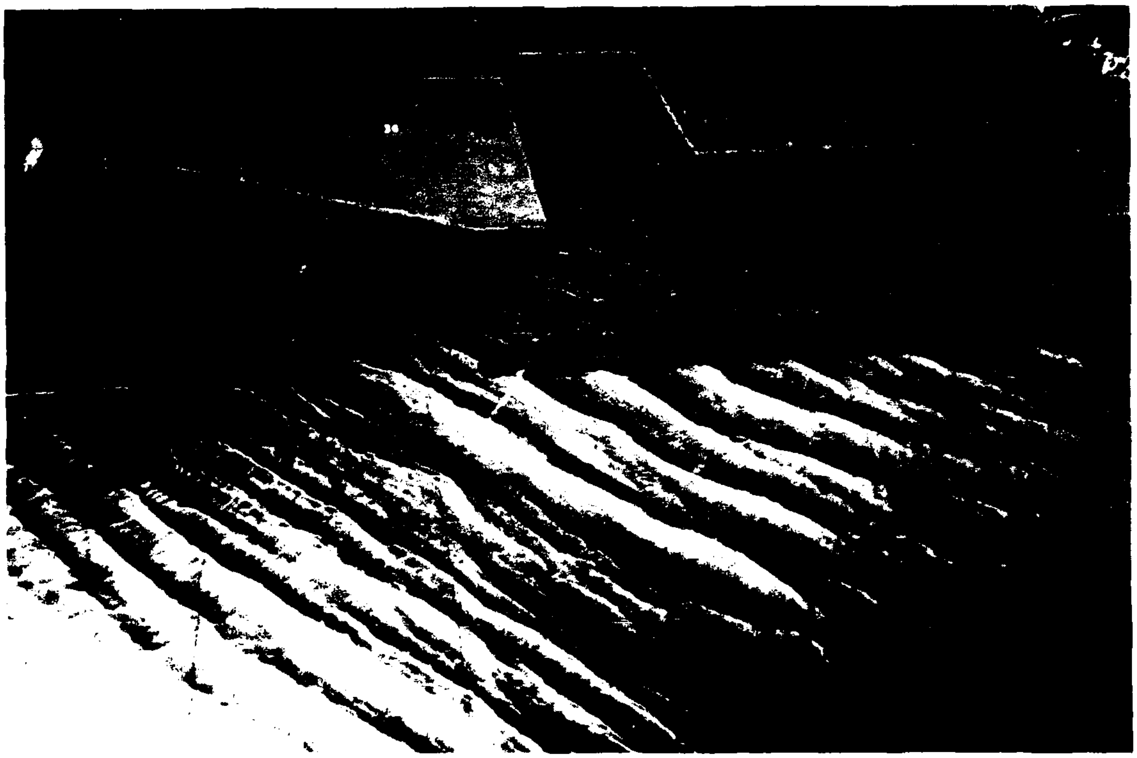


Photo 8. Typical wave patterns for Plan 10; 11-sec, 16-ft waves from 209 deg

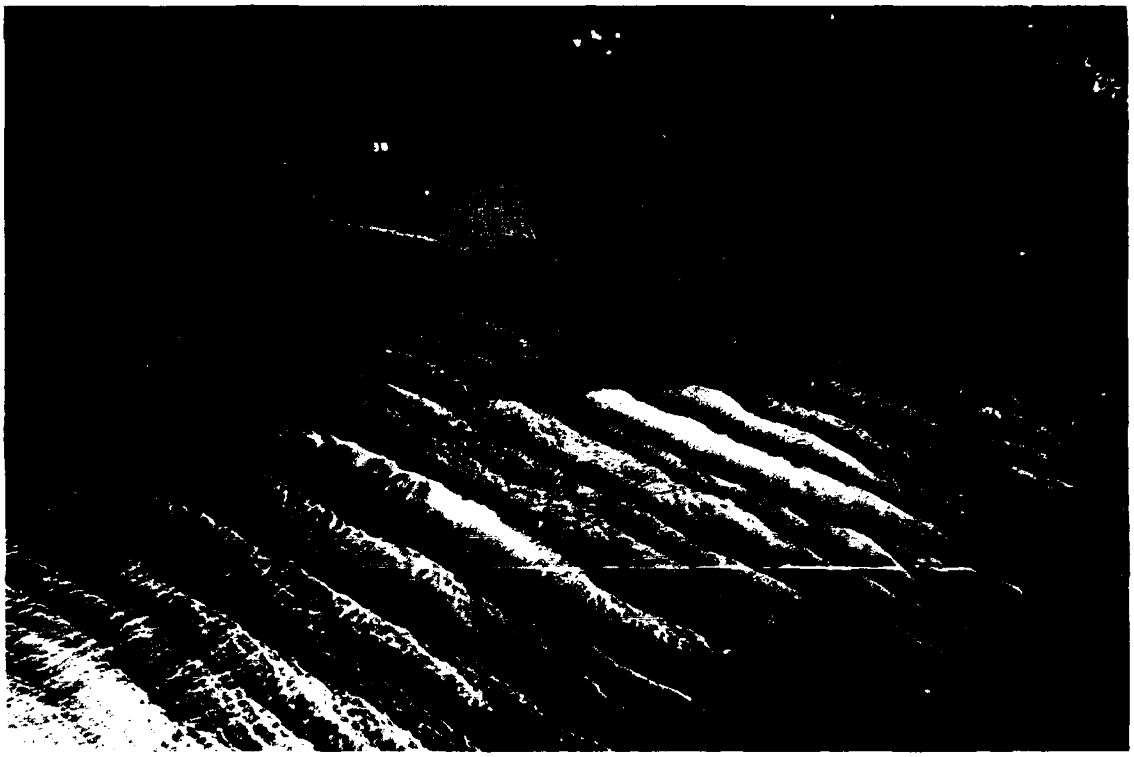


Photo 9. Typical wave patterns for Plan 11; 11-sec, 16-ft waves from 209 deg

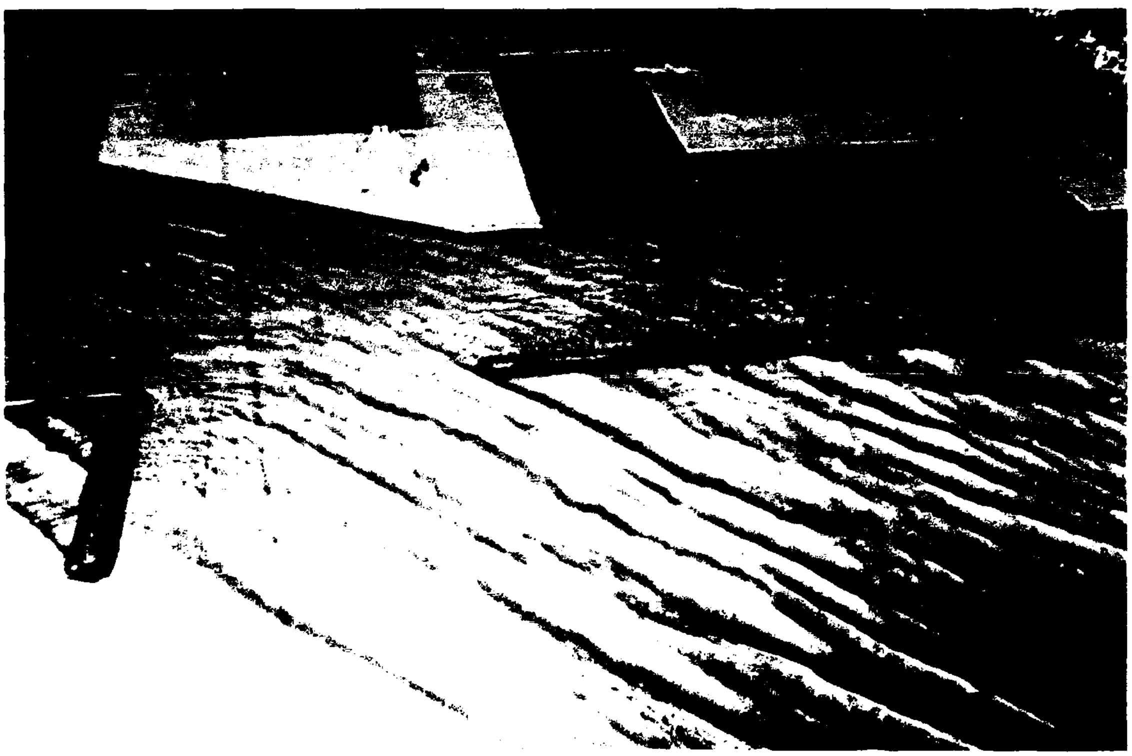


Photo 10. Typical wave patterns for Plan 12; 11-sec, 16-ft waves from 209 deg

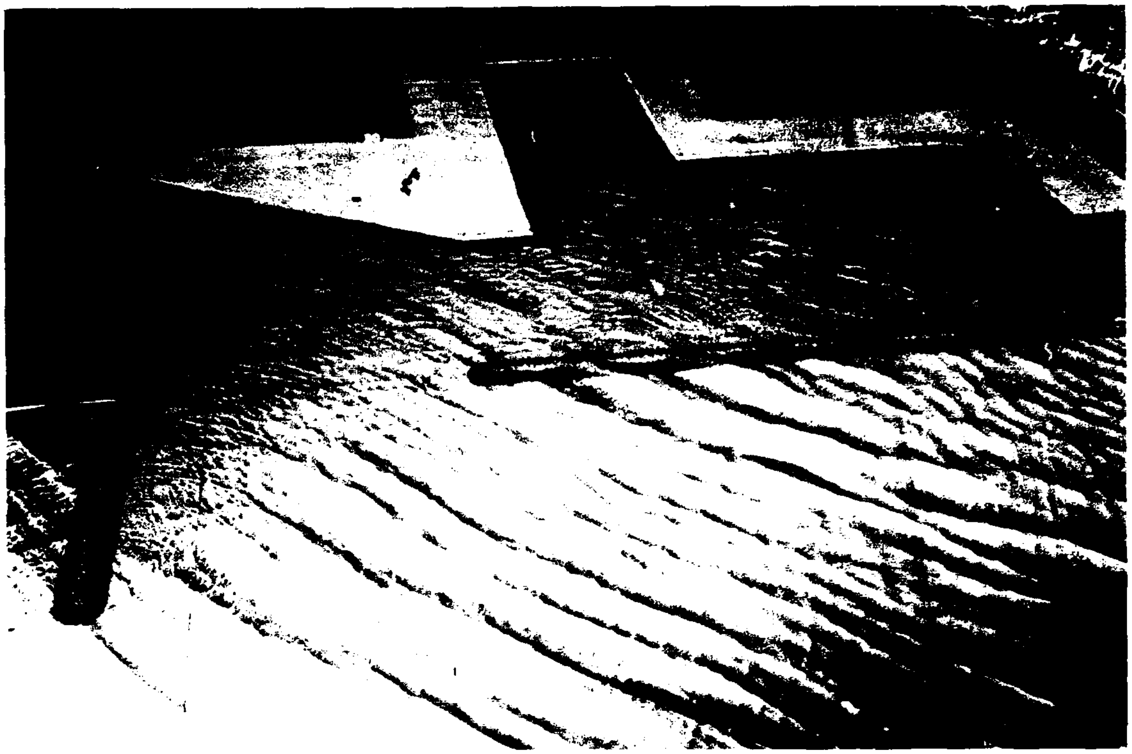


Photo 11. Typical wave patterns for Plan 13; 11-sec, 16-ft waves from 209 deg

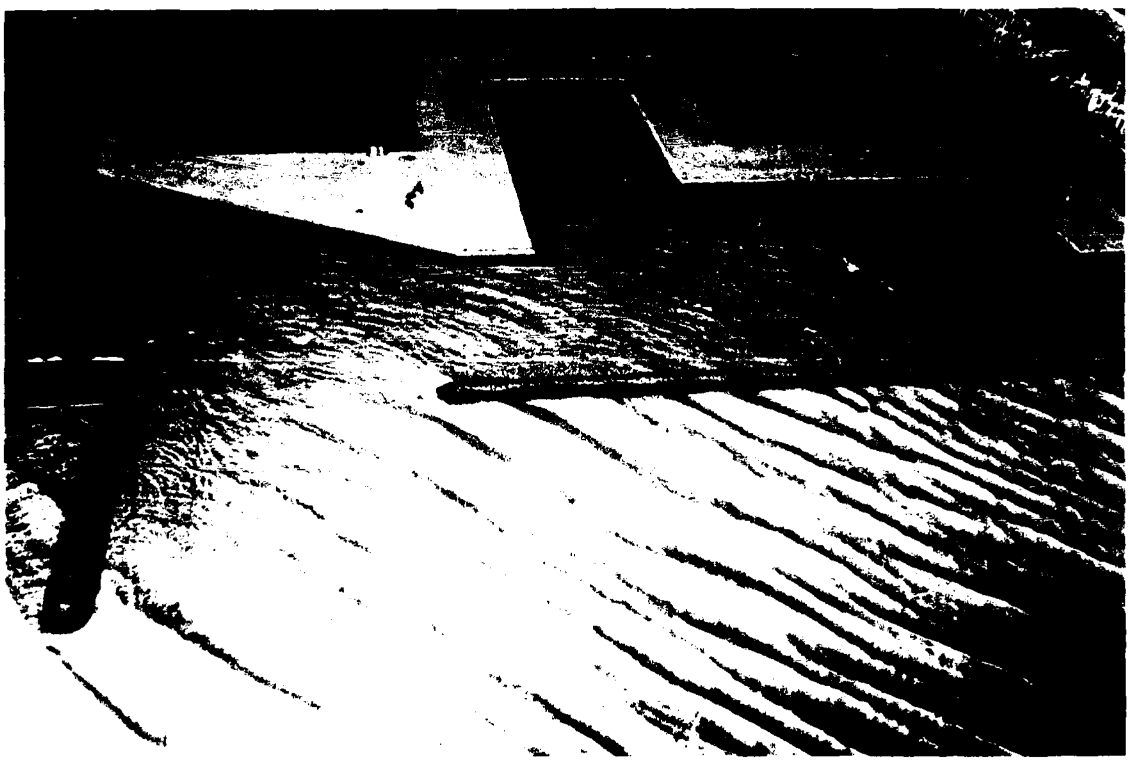


Photo 12. Typical wave patterns for Plan 14; 11-sec, 16-ft waves from 209 deg

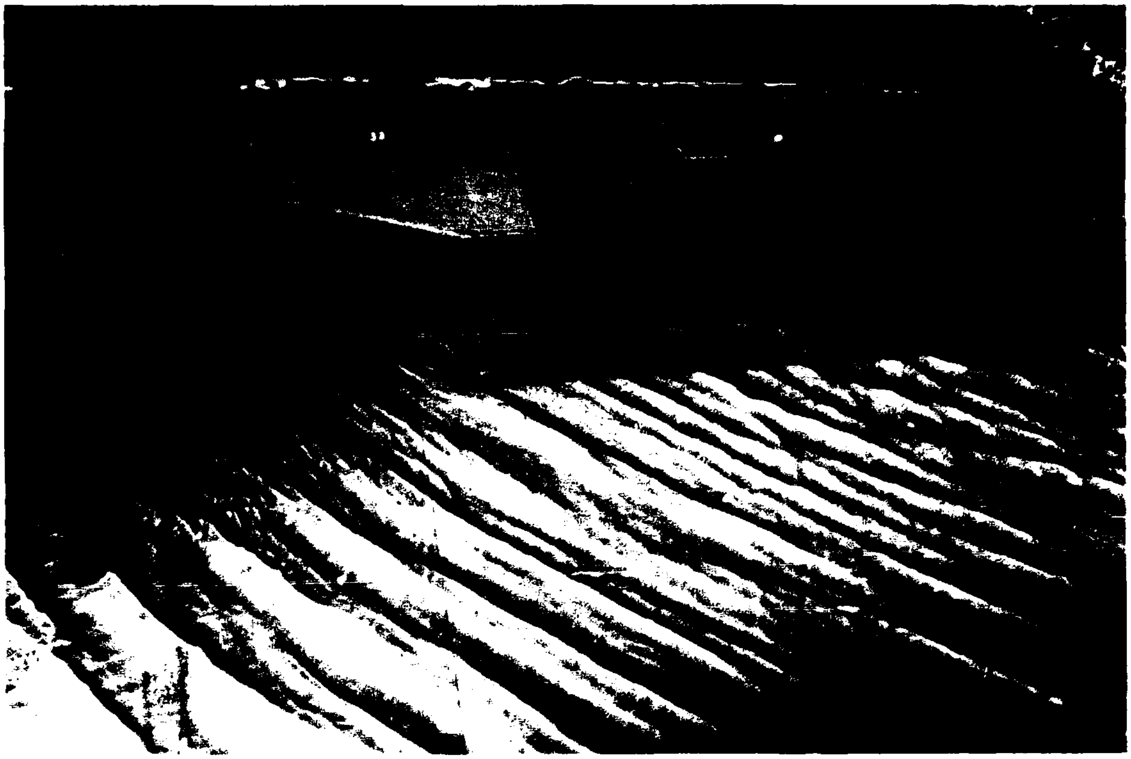


Photo 13. Typical wave patterns for Plan 15; 11-sec, 16-ft waves from 209 deg

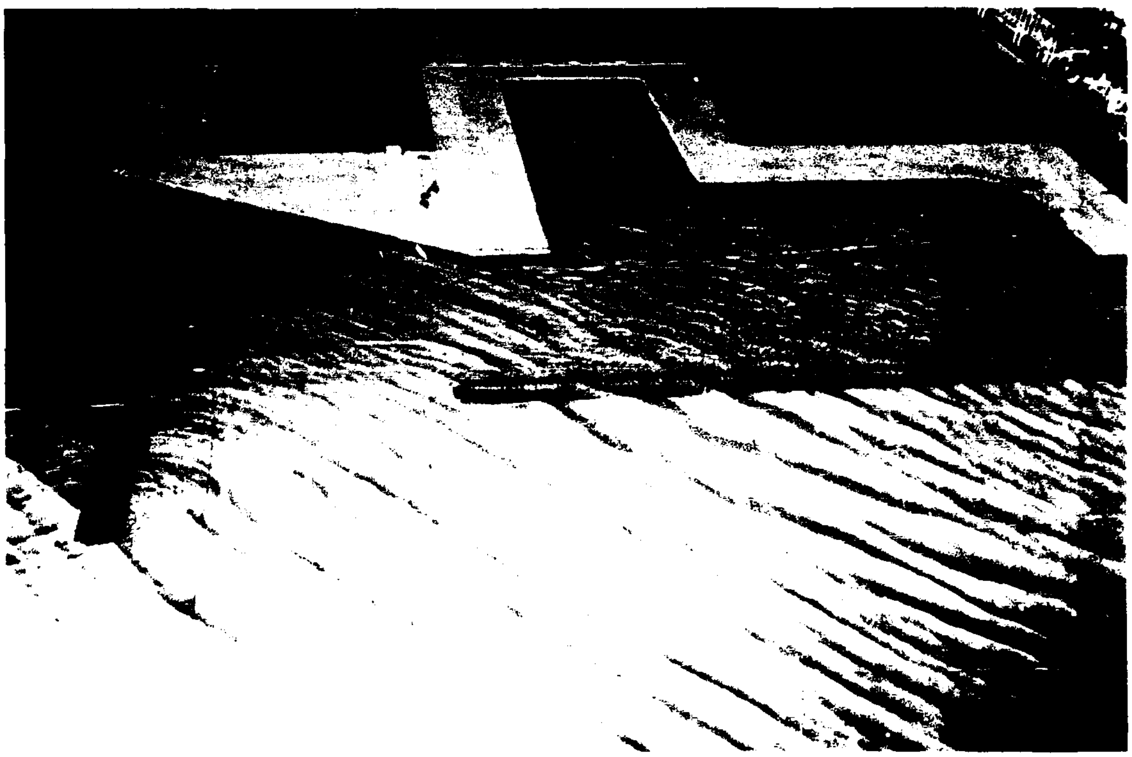


Photo 14. Typical wave patterns for Plan 16; 11-sec, 16-ft waves from 209 deg

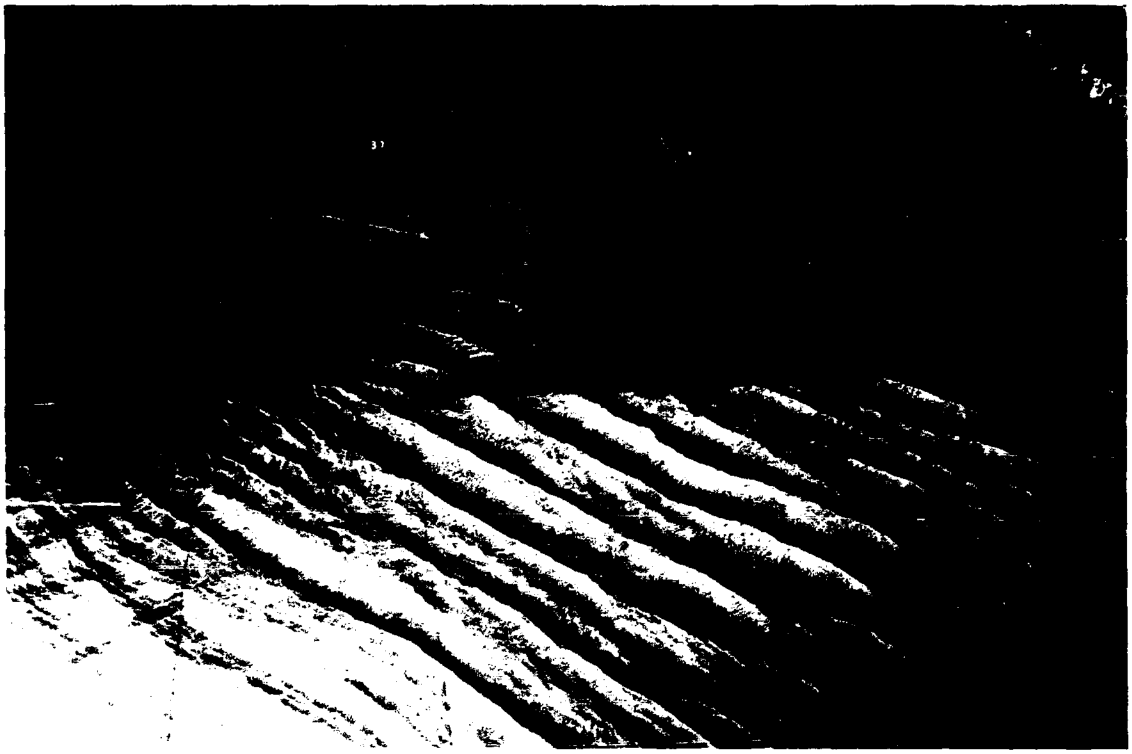


Photo 15. Typical wave patterns for Plan 17; 11-sec, 16-ft waves from 209 deg

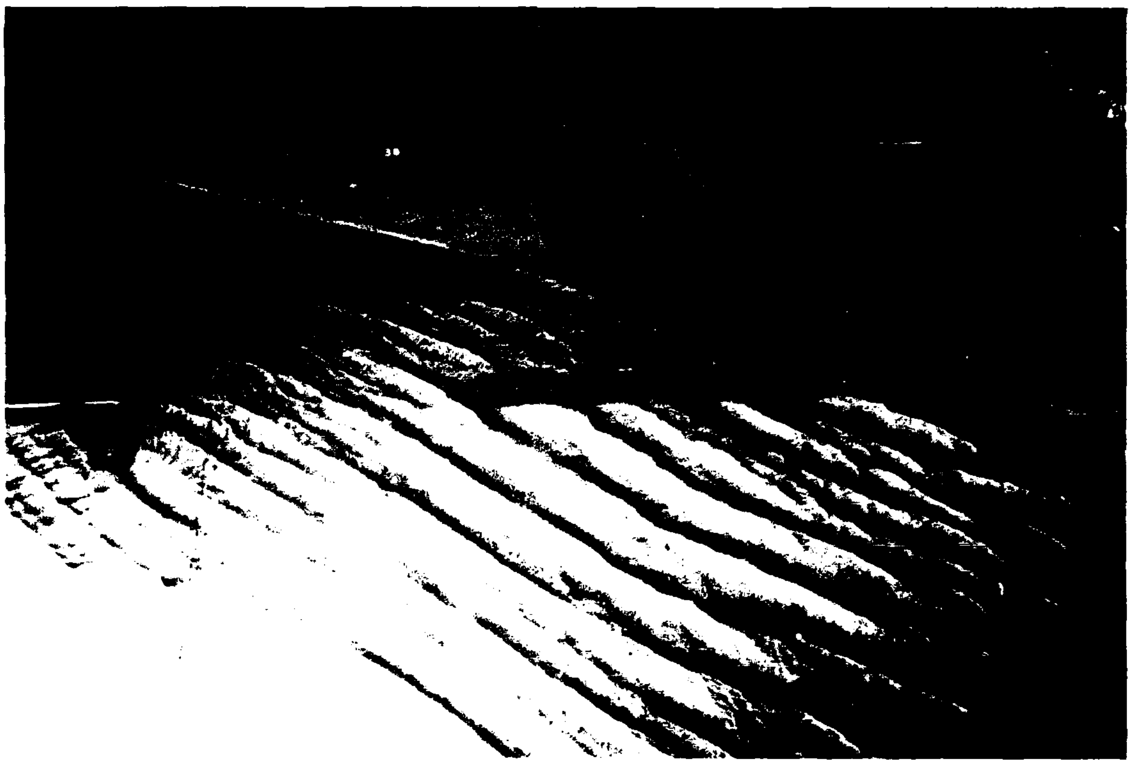


Photo 16. Typical wave patterns for Plan 18; 11-sec, 16-ft waves from 209 deg

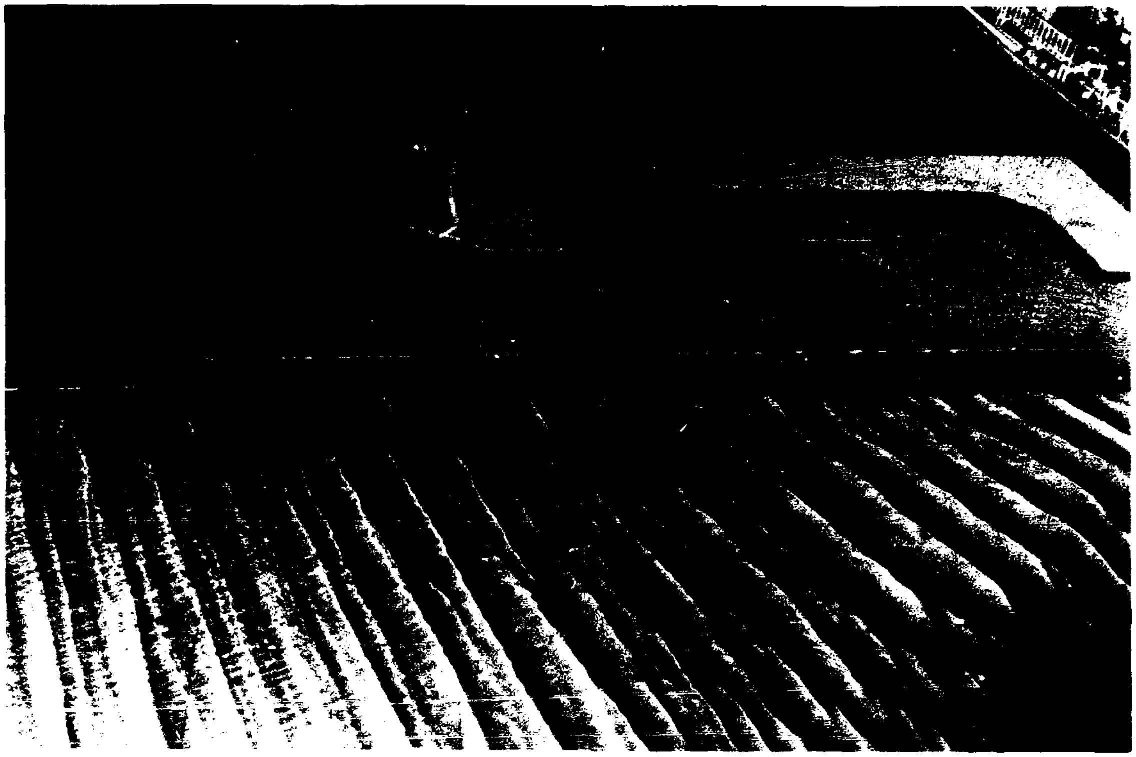


Photo 17. Typical wave patterns for Plan 9; 9-sec, 14-ft waves from 231 deg

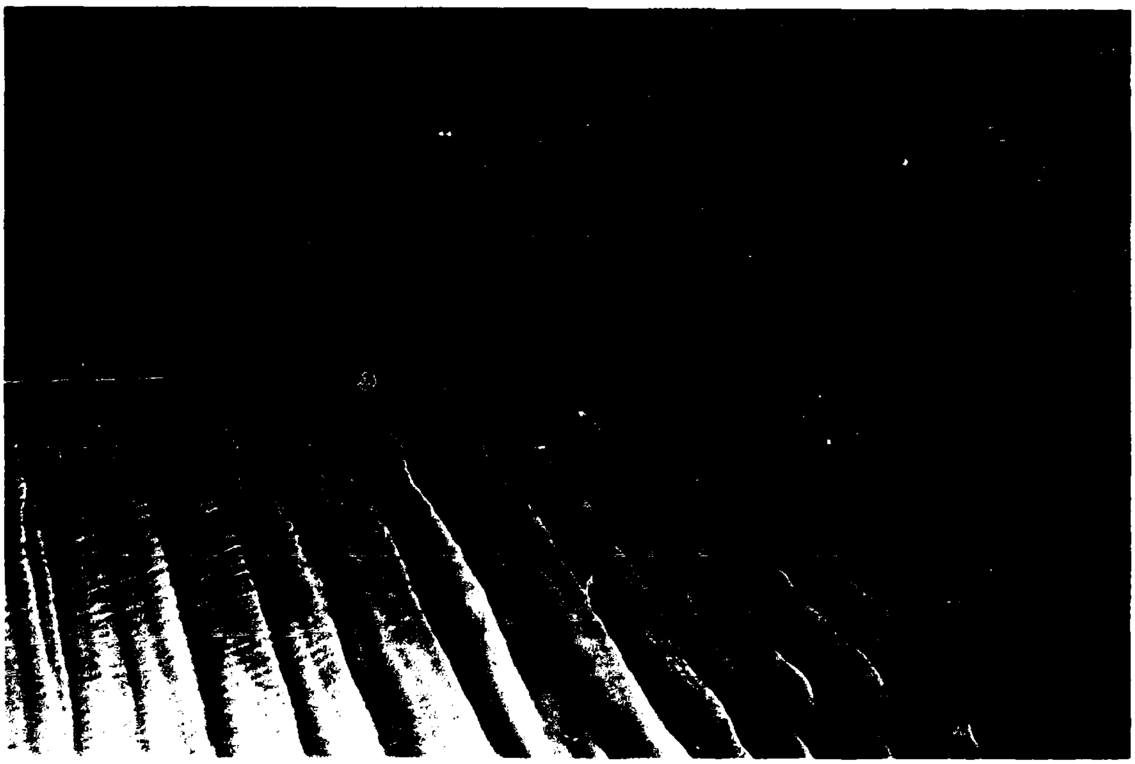


Photo 18. Typical wave patterns for Plan 18; 9-sec, 14-ft waves from 231 deg

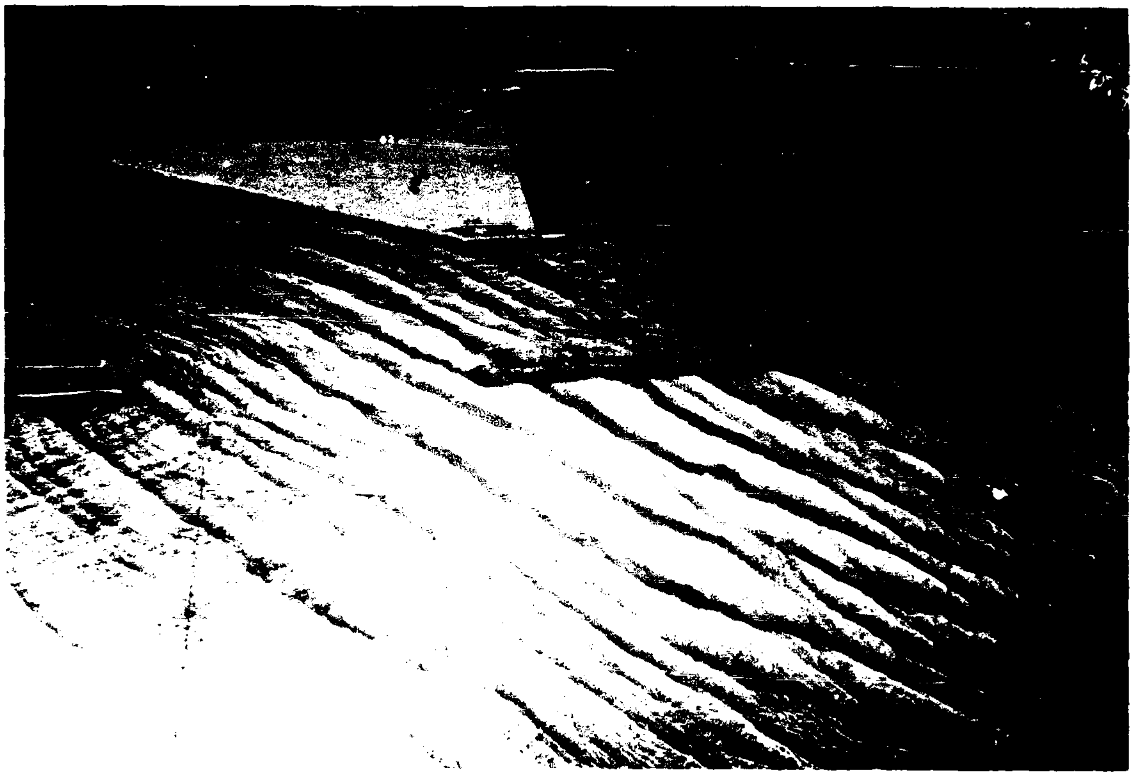
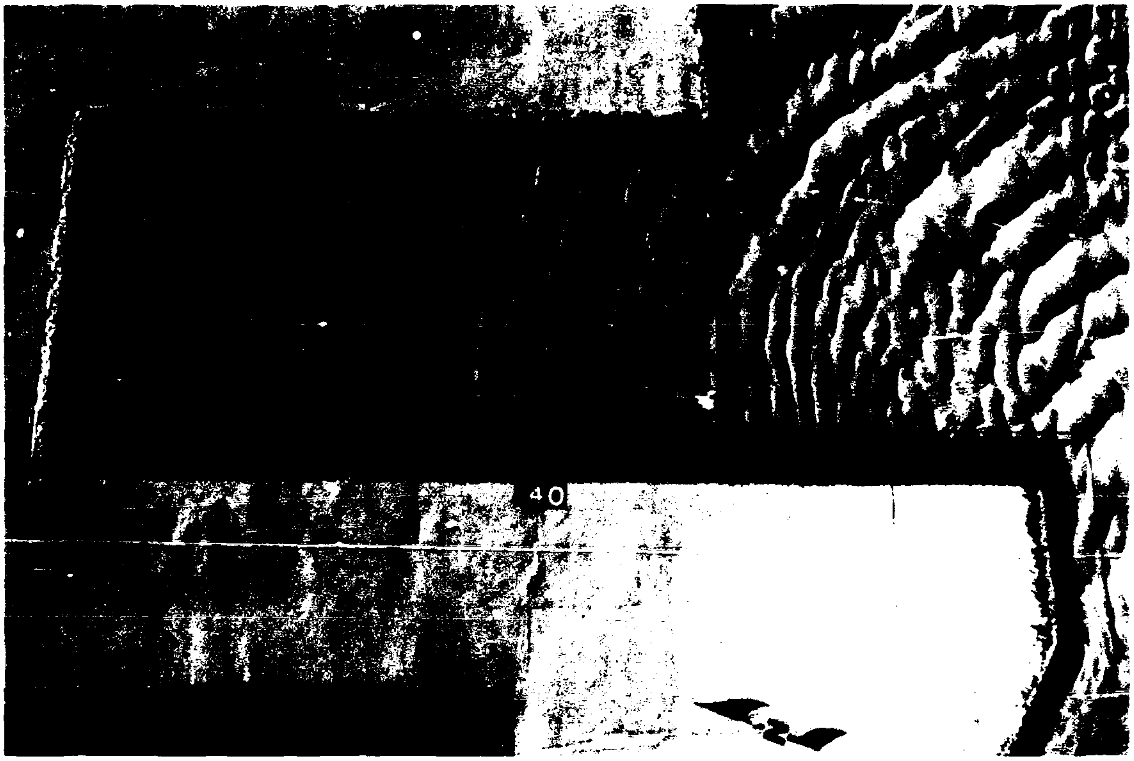


Photo 19. Typical wave patterns for Plan 19; 11-sec, 16-ft waves from 209 deg



a. Typical wave patterns for Plan 1

b. Typical wave patterns for Plan 19

Photo 20. Comparison of wave conditions in the proposed container terminal area for Plans 1 and 19; 11-sec, 16-ft waves from 209 deg

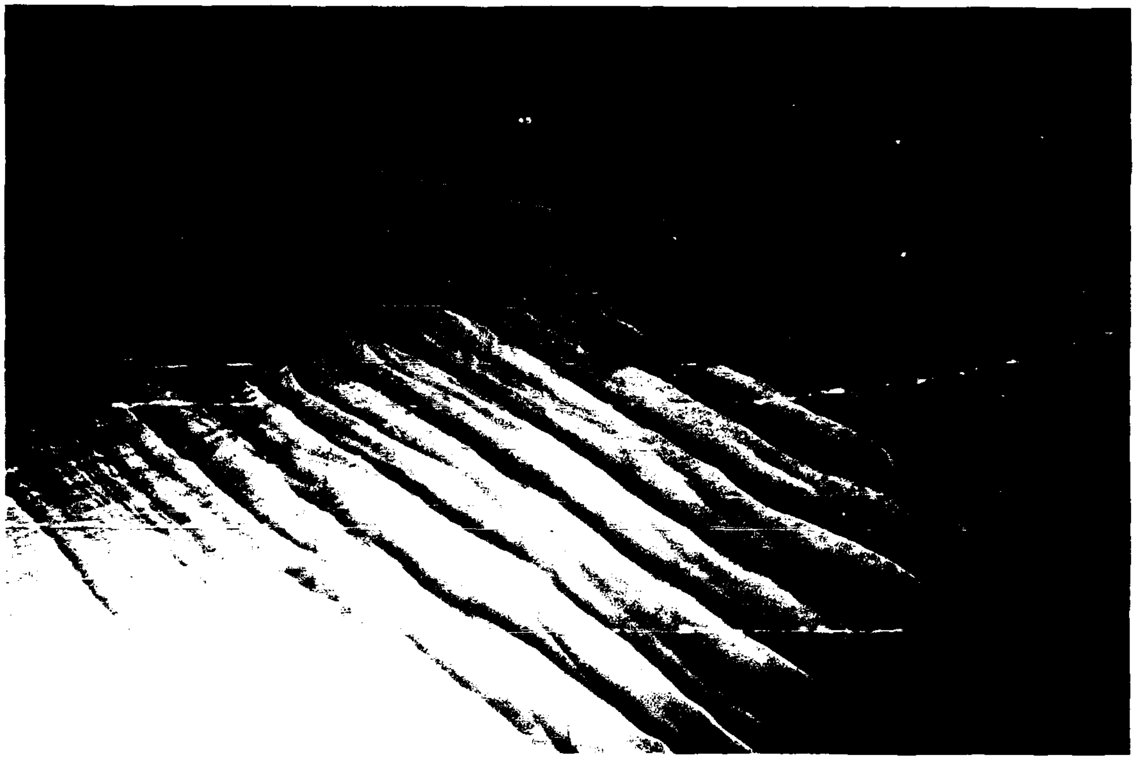


Photo 21. Typical wave patterns for Plan 20; 11-sec, 16-ft waves from 209 deg

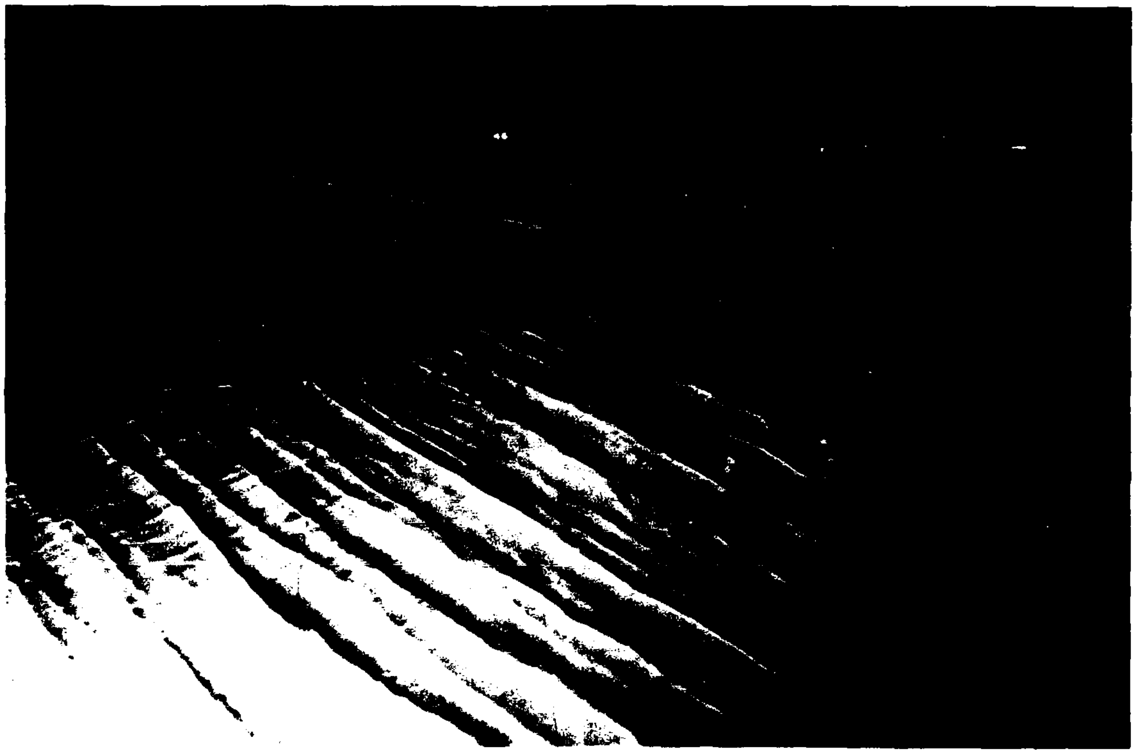


Photo 22. Typical wave patterns for Plan 21; 11-sec, 16-ft waves from 209 deg

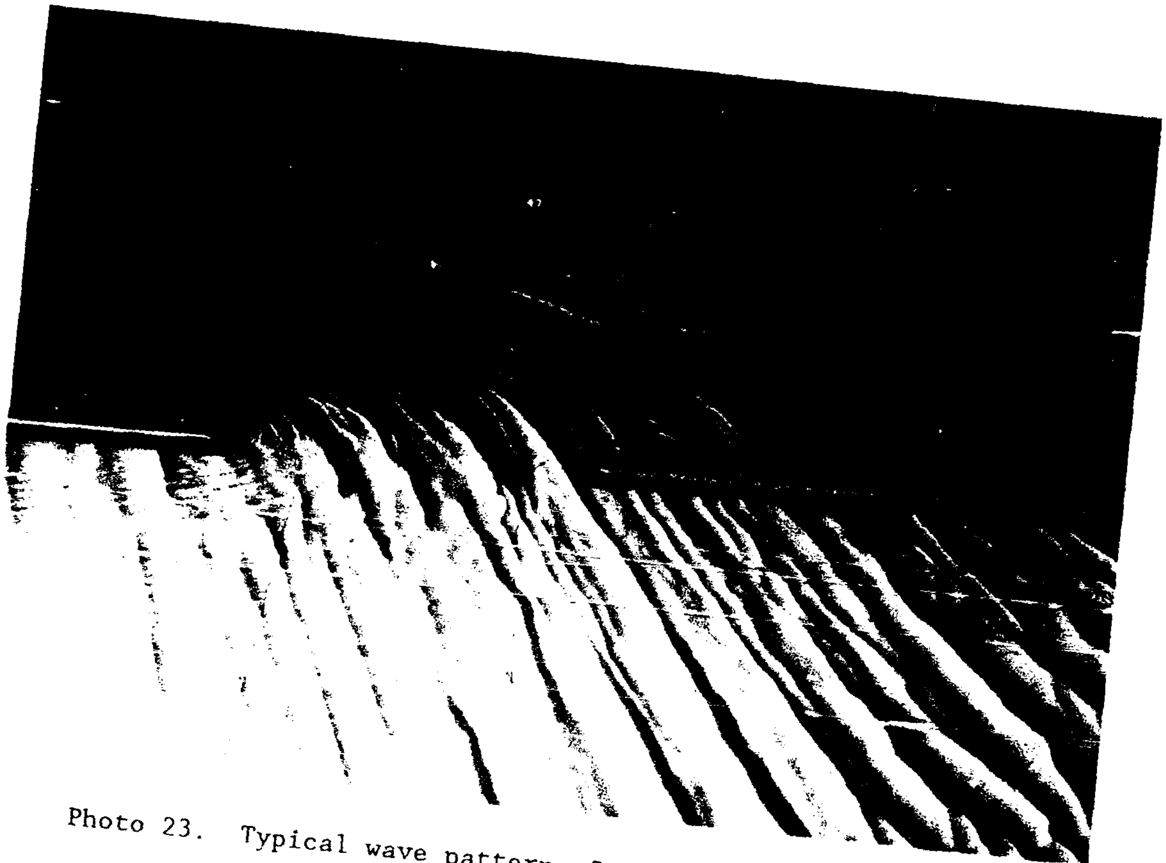


Photo 23. Typical wave patterns for Plan 20; 9-sec, 14-ft waves from 231 deg

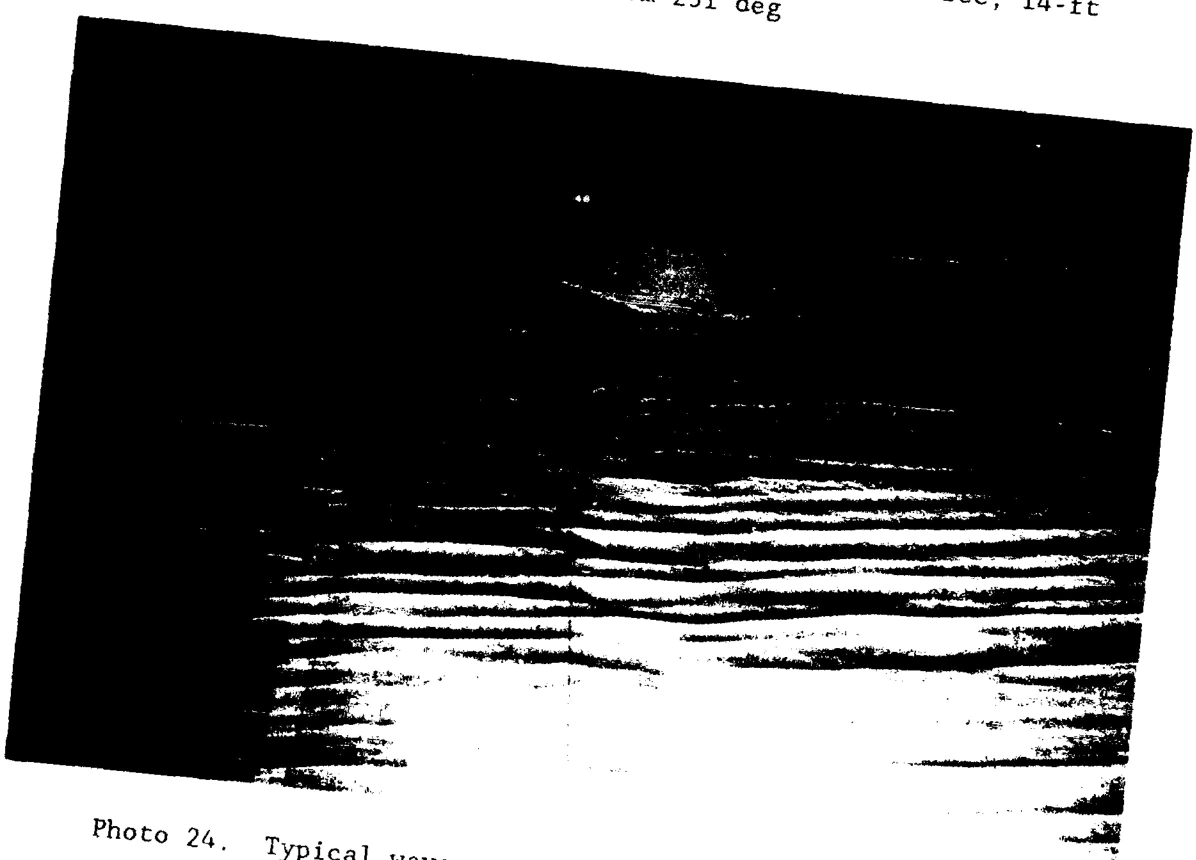


Photo 24. Typical wave patterns for Plan 20; 11-sec, 10-ft waves from 154 deg

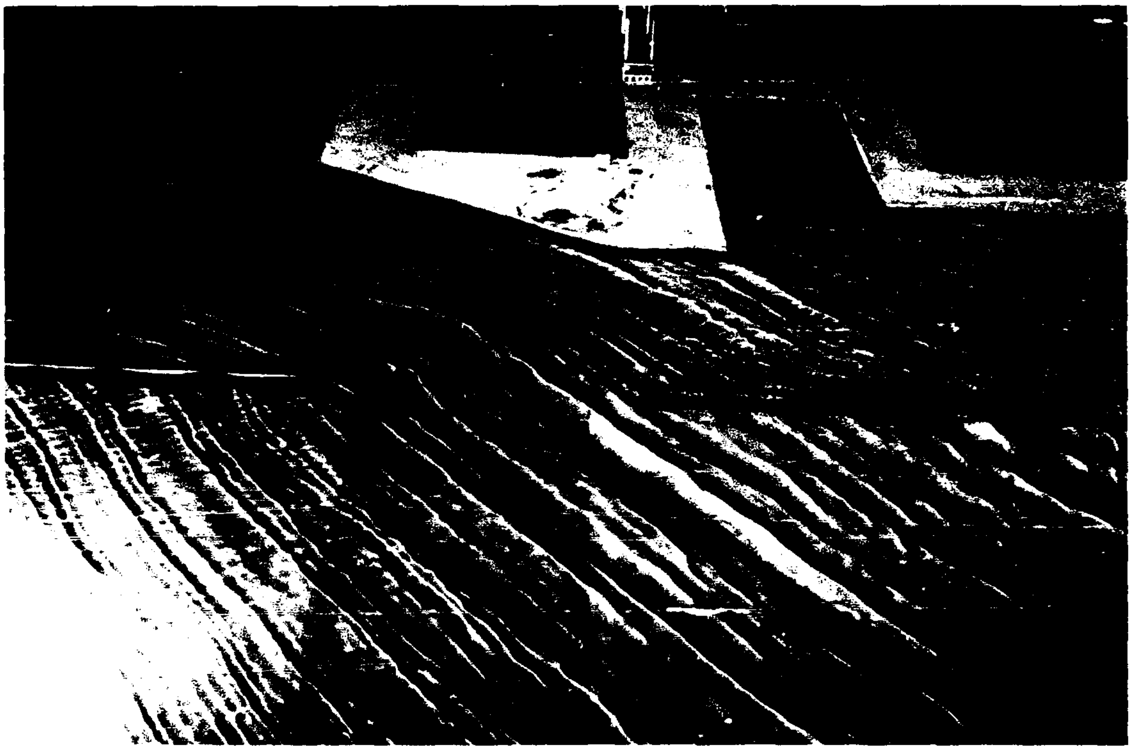


Photo 25. Typical wave patterns for Plan 22; 11-sec, 16-ft waves from 209 deg

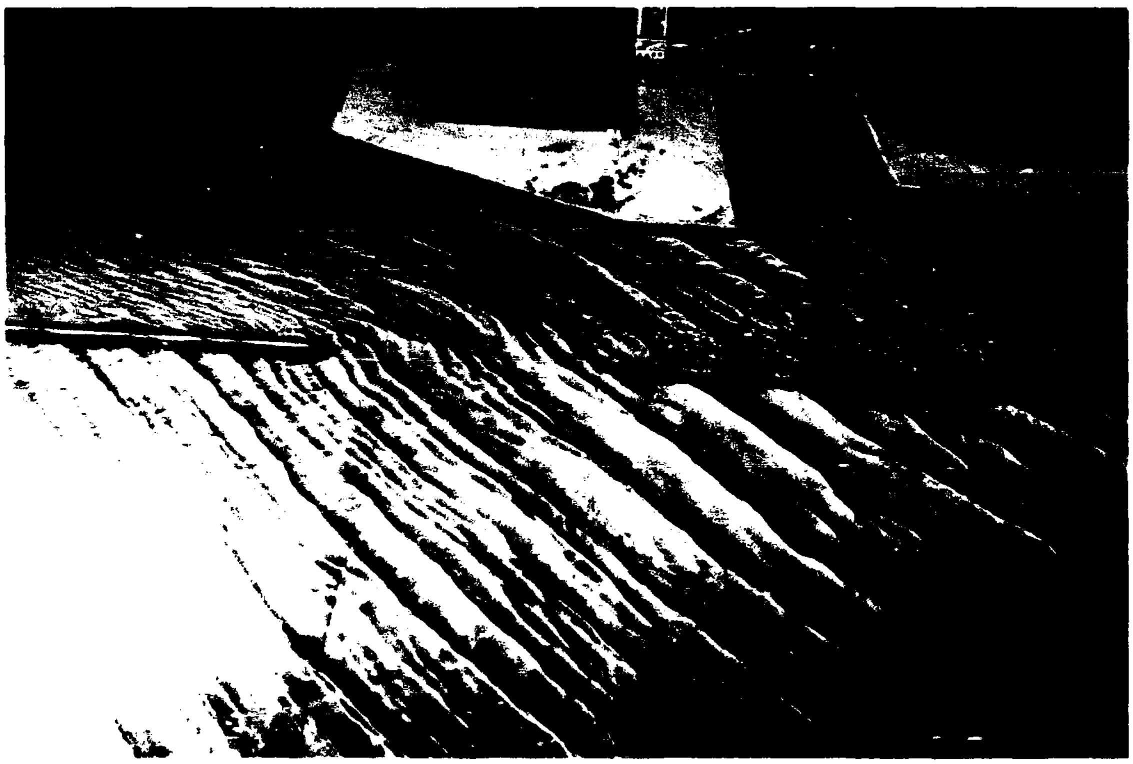


Photo 26. Typical wave patterns for Plan 23; 11-sec, 16-ft waves from 209 deg

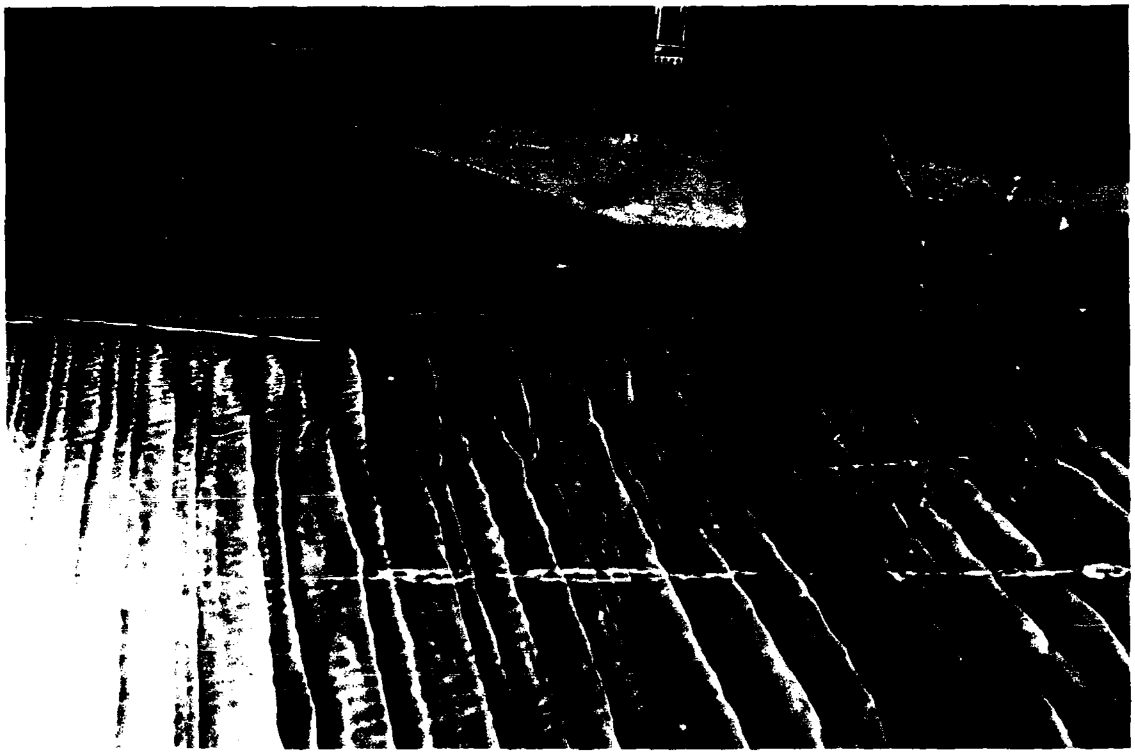


Photo 27. Typical wave patterns for Plan 22; 9-sec, 14-ft waves from 231 deg

Photo 28. Typical wave patterns for Plan 22; 11-sec, 10-ft waves from 154 deg

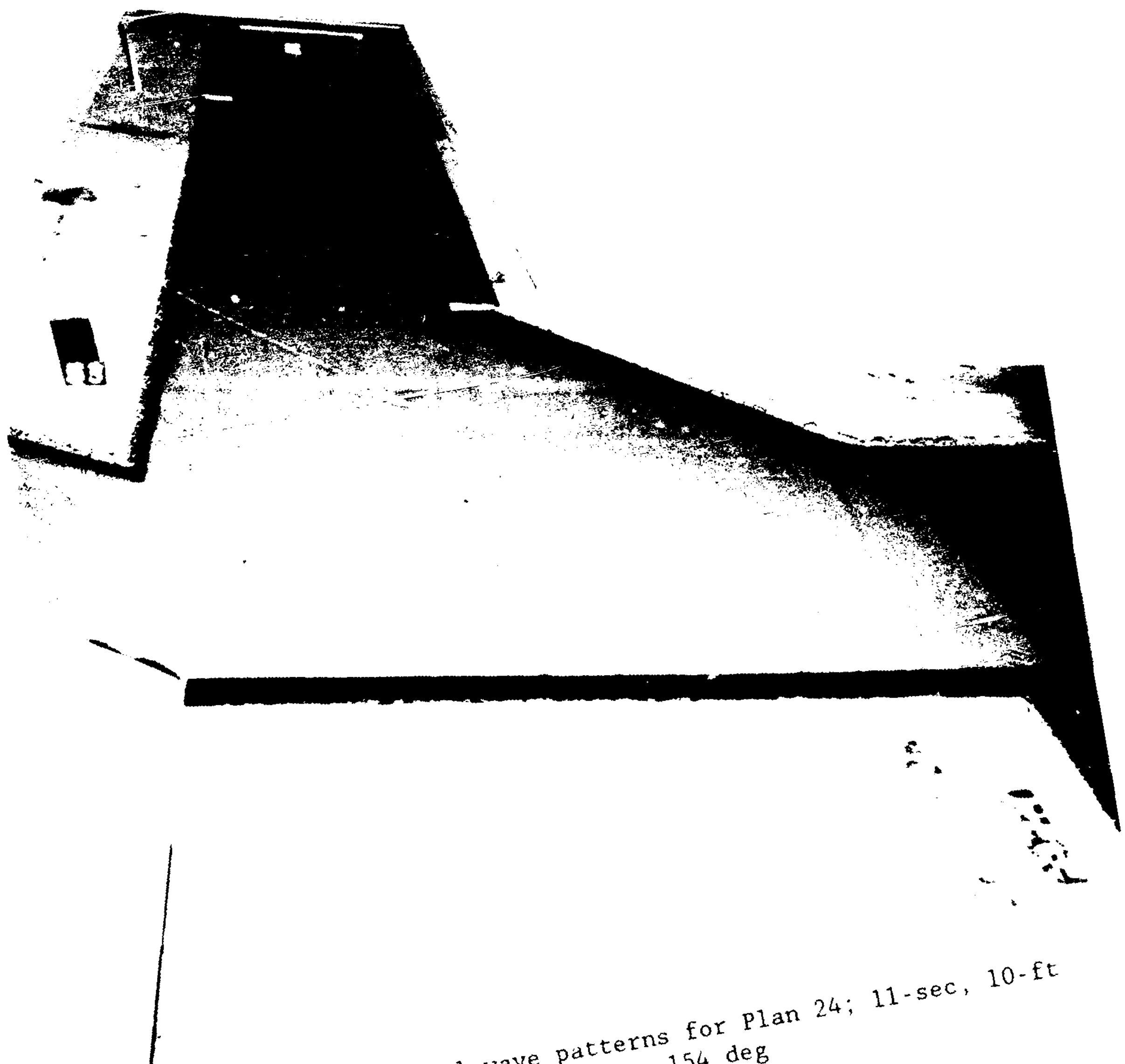
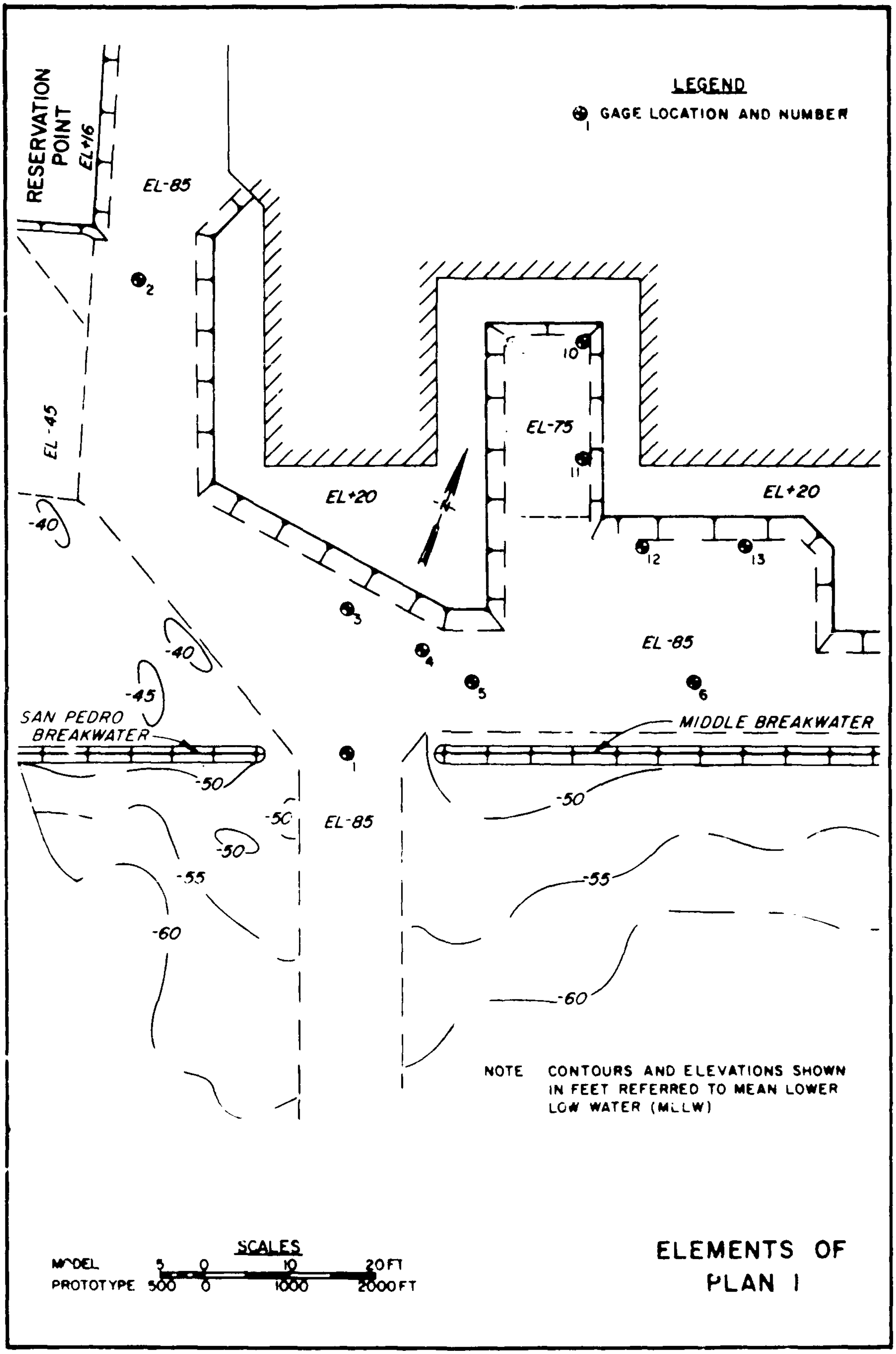
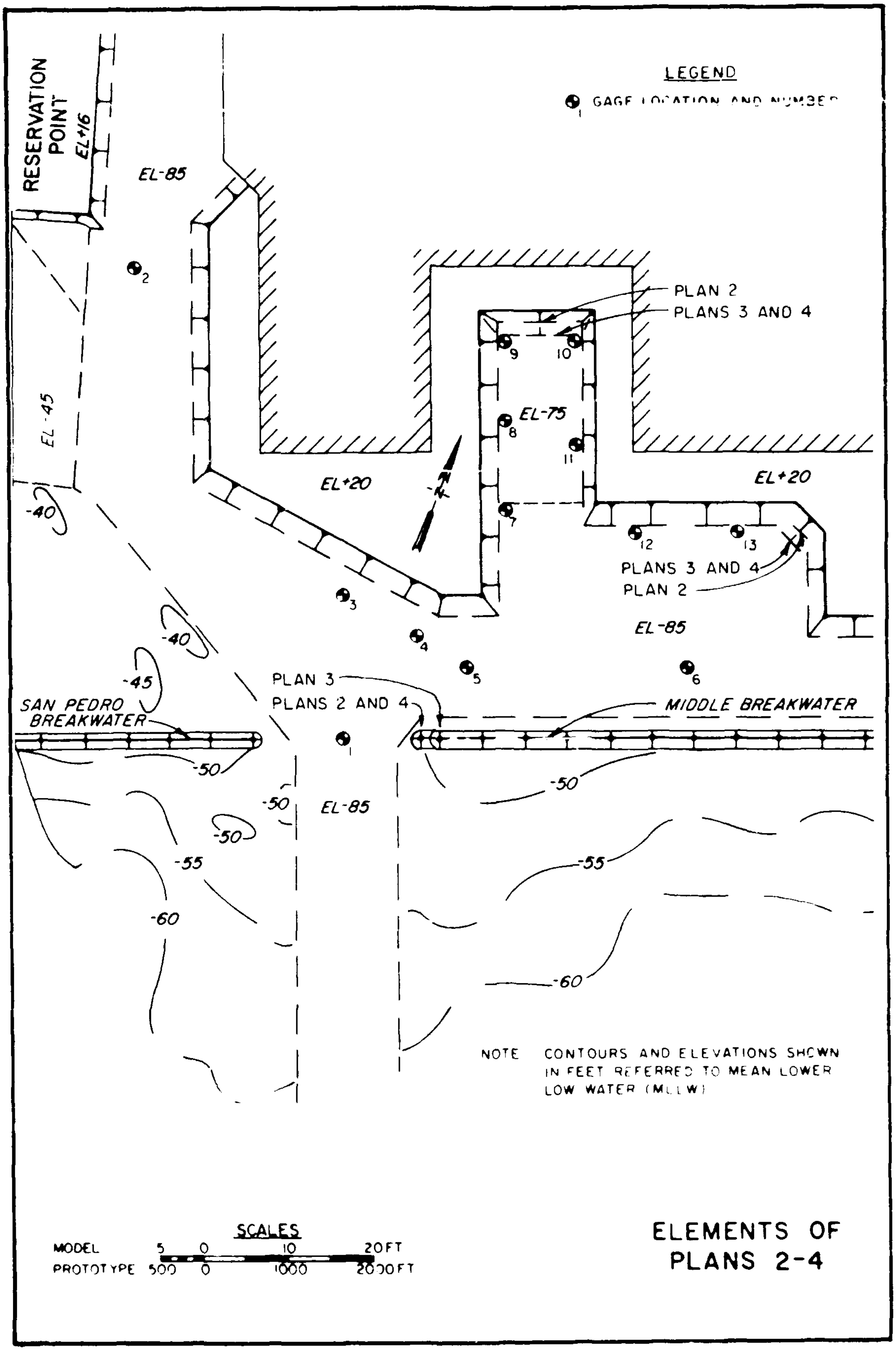


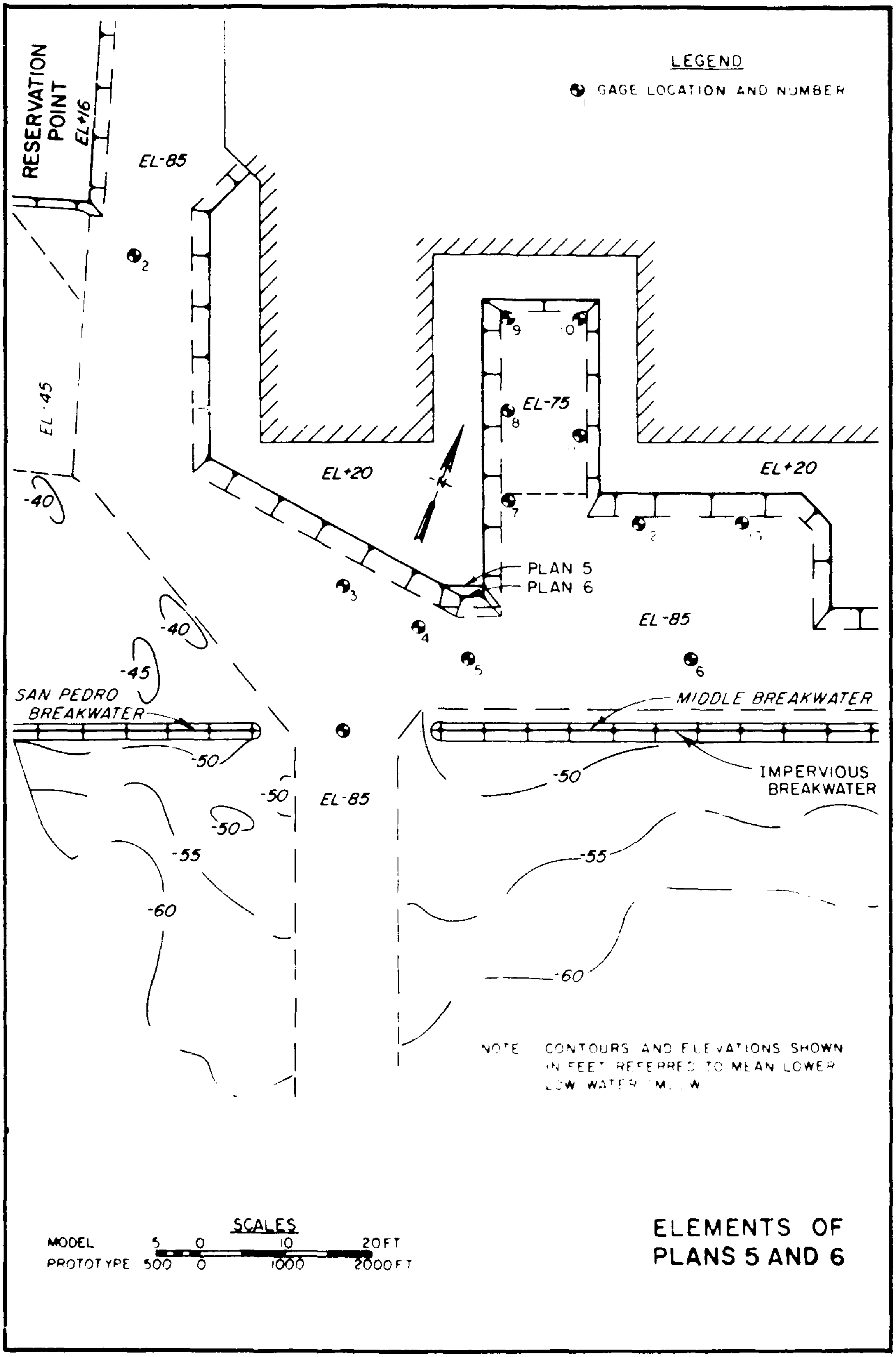
Photo 29. Typical wave patterns for Plan 24; 11-sec, 10-ft waves from 154 deg



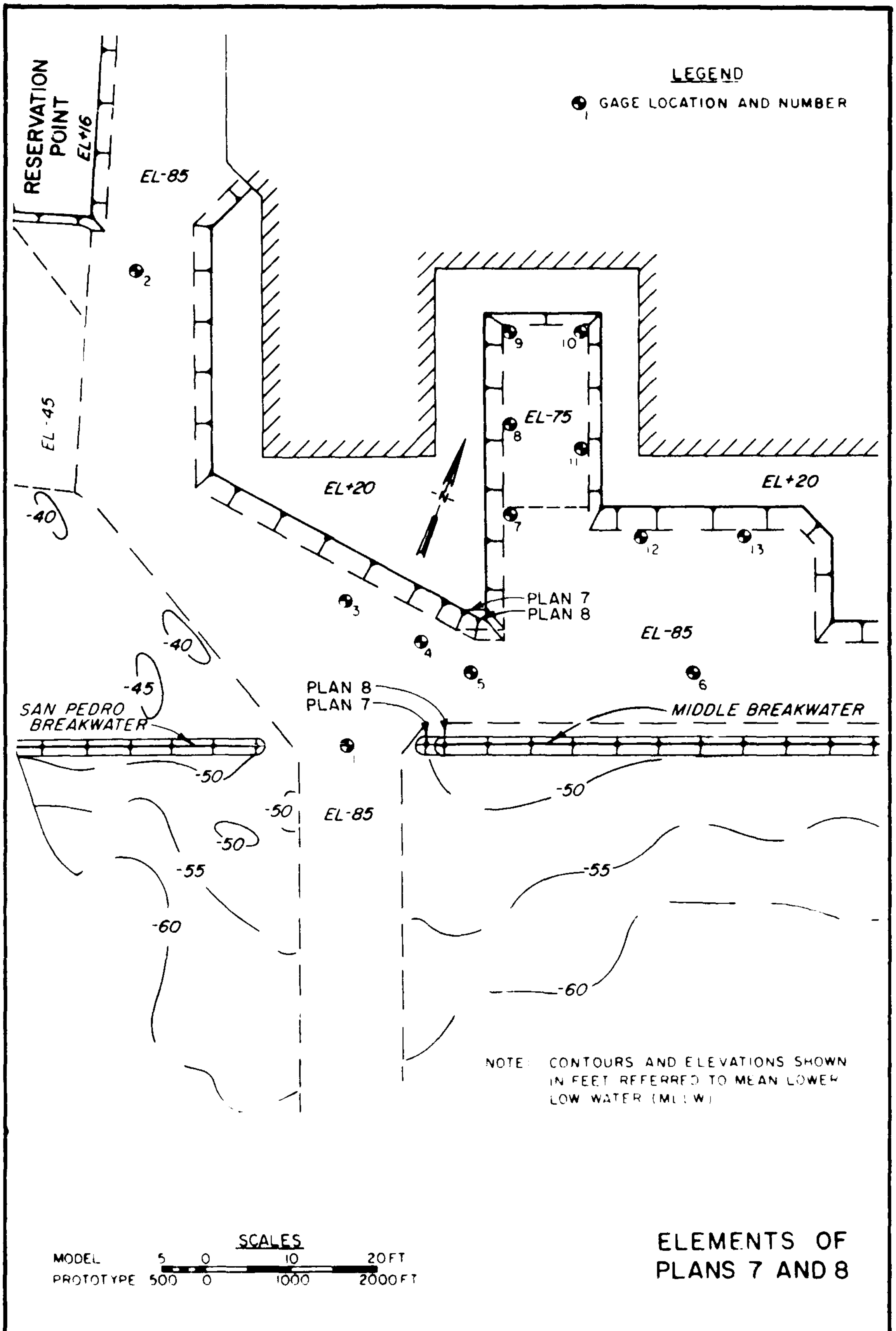
ELEMENTS OF PLAN 1



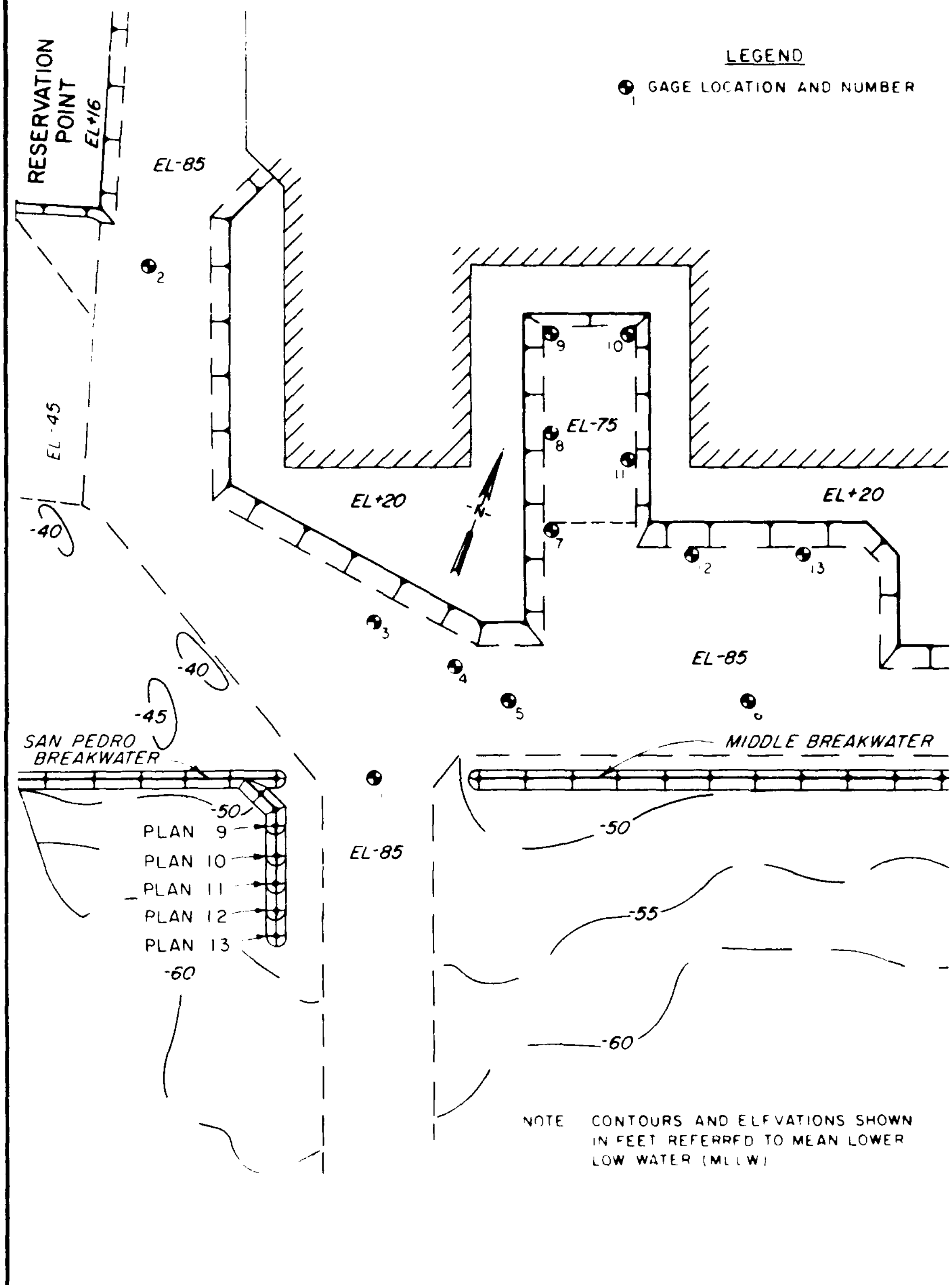
ELEMENTS OF PLANS 2-4



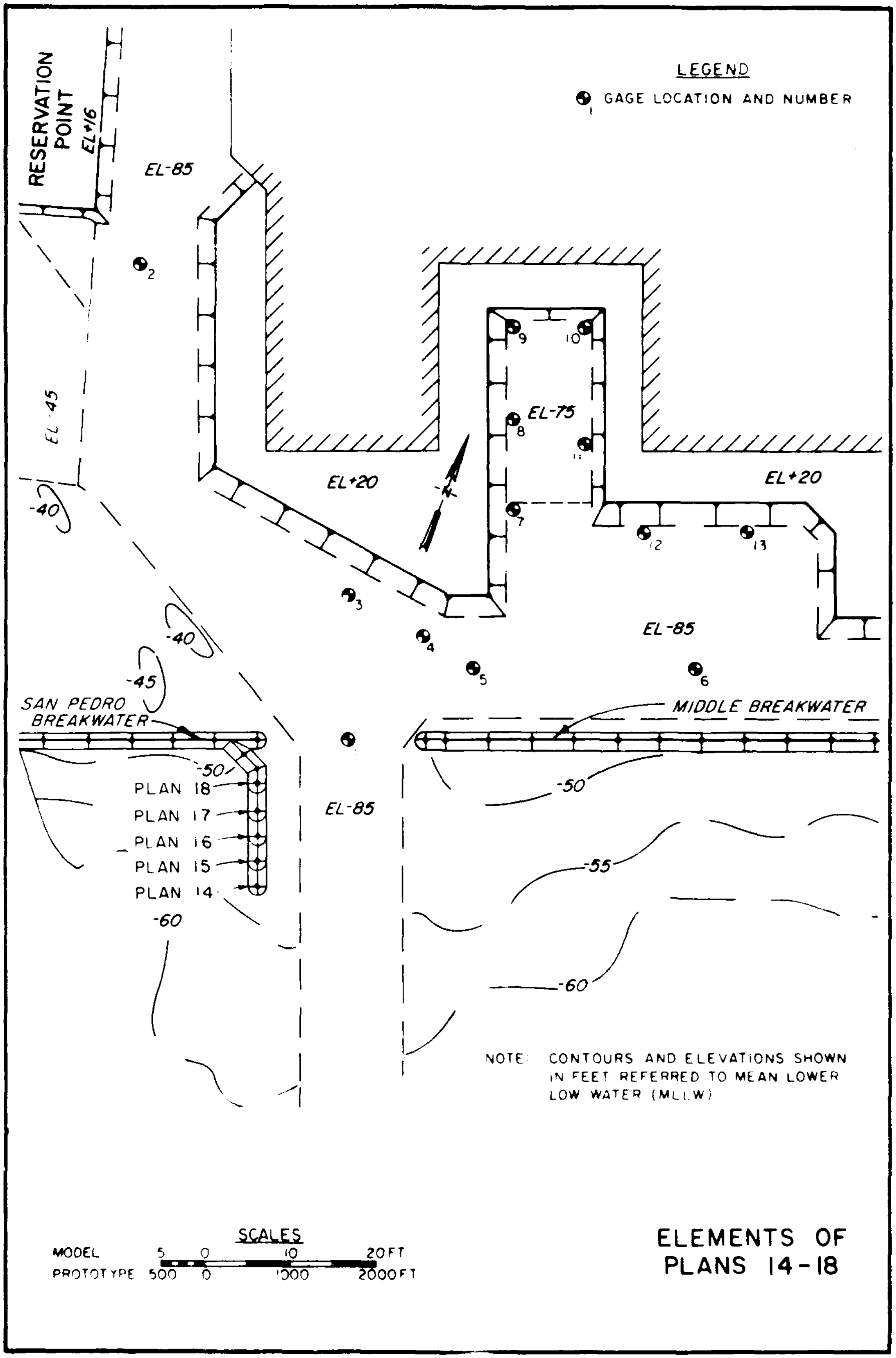
ELEMENTS OF PLANS 5 AND 6



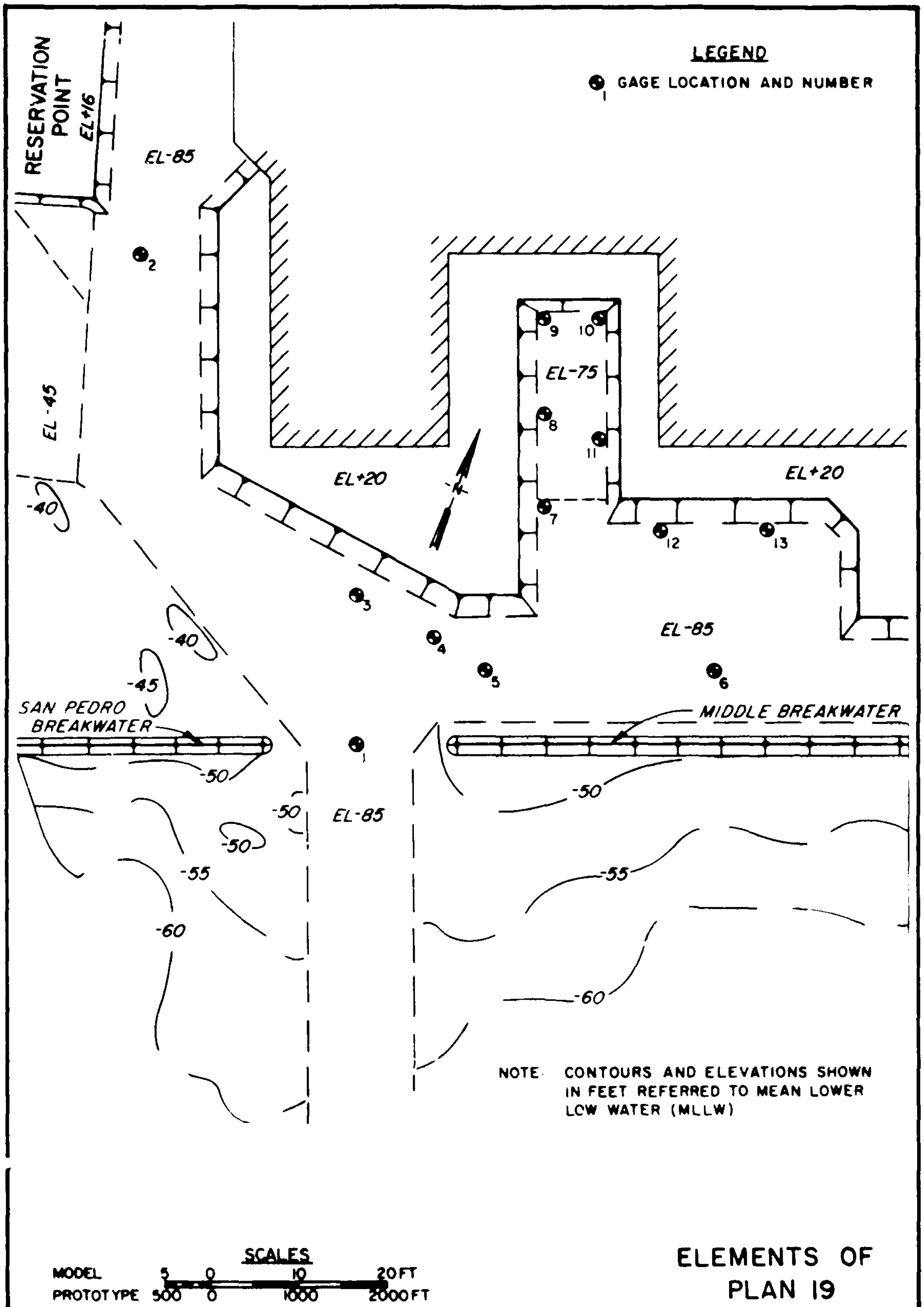
ELEMENTS OF PLANS 7 AND 8



ELEMENTS OF PLANS 9-13



ELEMENTS OF PLANS 14-18



ELEMENTS OF PLAN 19

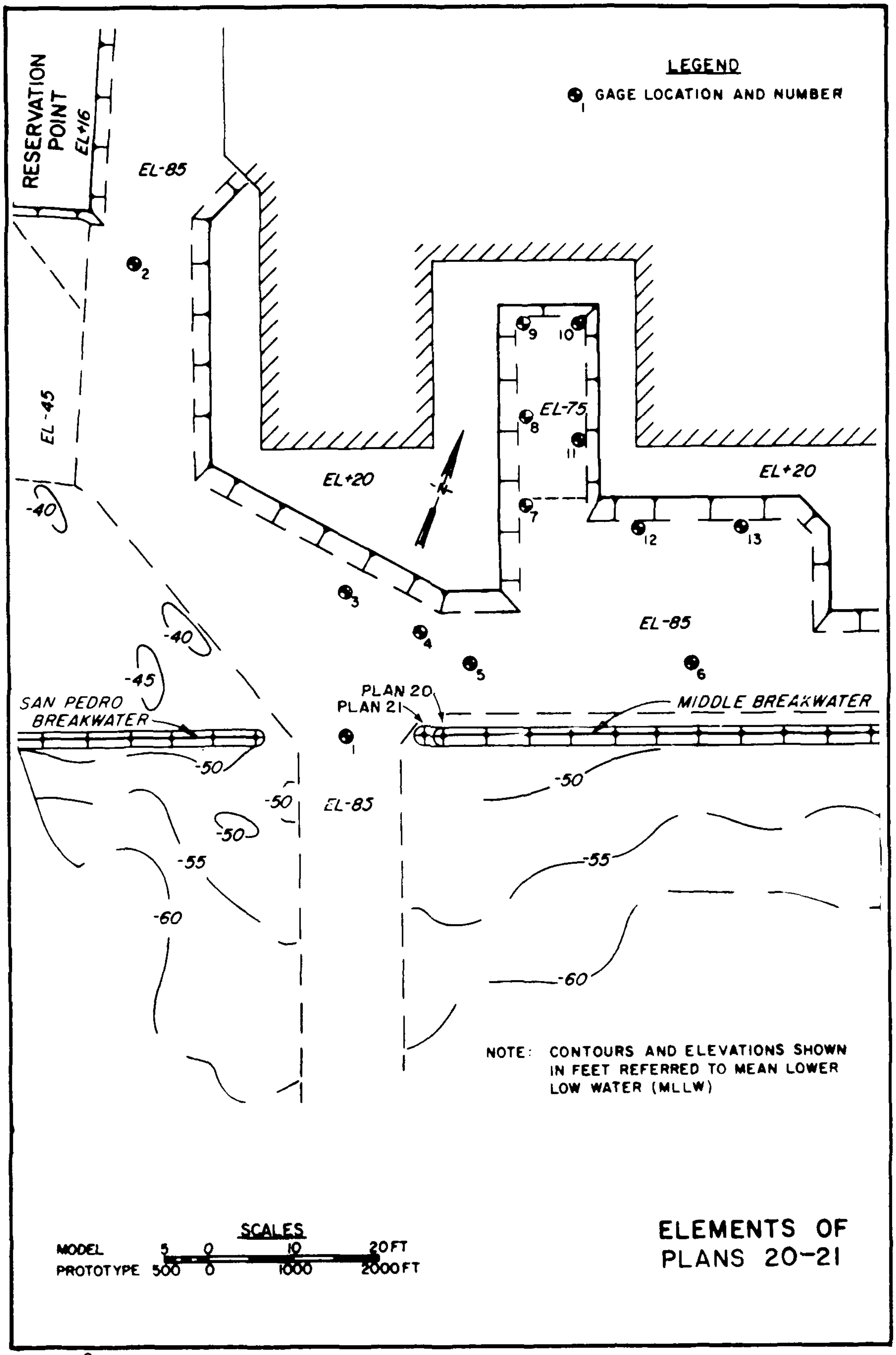
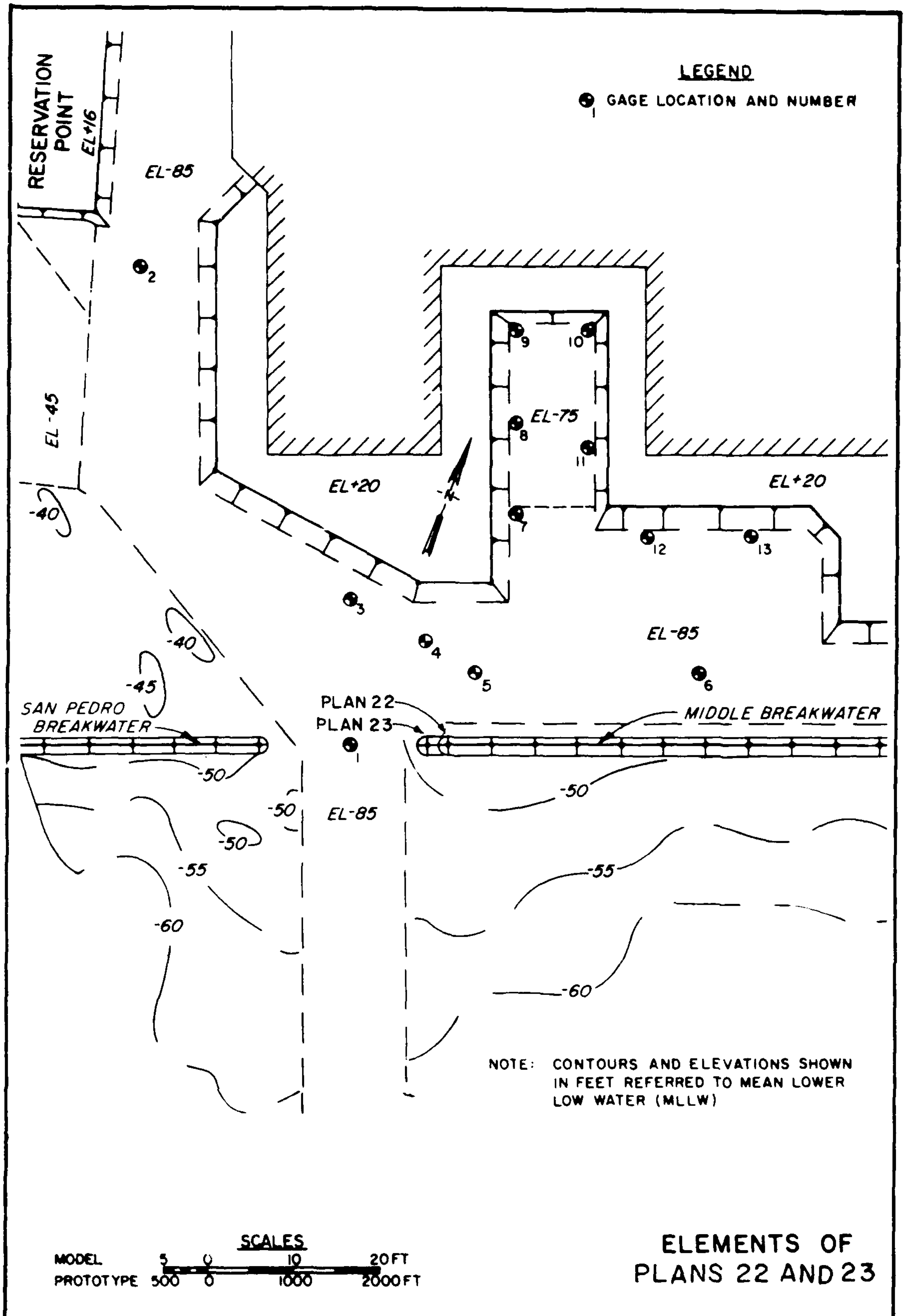
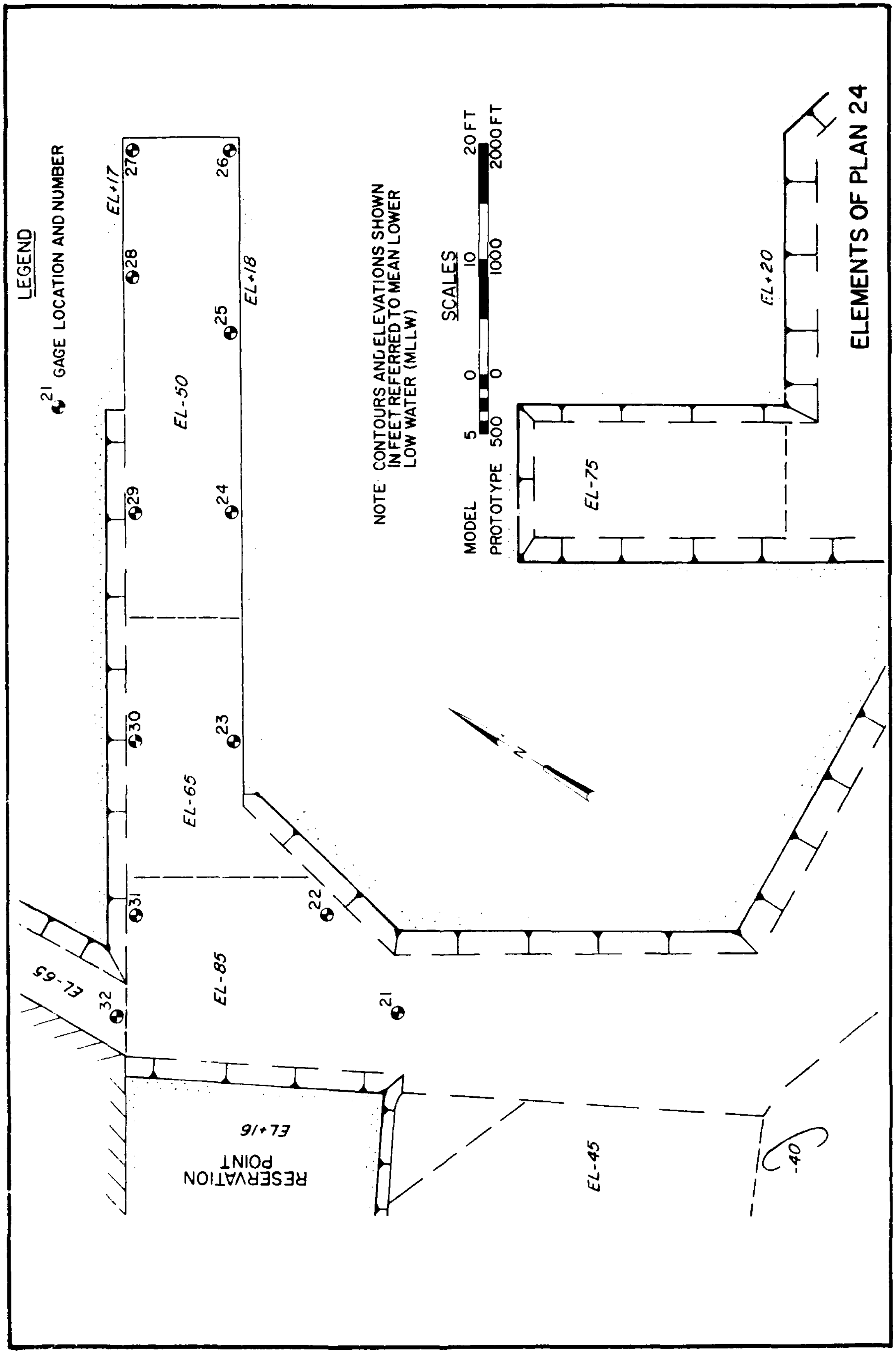

LEGEND
GAGE LOCATION AND NUMBER
RESERVATION POINT
EL+16
EL-85
EL-45
EL+20
EL-75
EL+20
EL-85
N
SAN PEDRO BREAKWATER
PLAN 20
PLAN 21
MIDDLE BREAKWATER
EL-85
-40
-40
-45
-50
-50
-50
-50
-55
-55
-60
-60
NOTE: CONTOURS AND ELEVATIONS SHOWN IN FEET REFERRED TO MEAN LOWER LOW WATER (MLLW)
SCALES
MODEL 5 0 10 20 FT
PROTOTYPE 500 0 1000 2000 FT
ELEMENTS OF PLANS 20-21

PLATE 8



ELEMENTS OF PLANS 22 AND 23


ELEMENTS OF PLAN 24
LEGEND
21 GAGE LOCATION AND NUMBER
NOTE: CONTOURS AND ELEVATIONS SHOWN IN FEET REFERRED TO MEAN LOWER LOW WATER (MLLW)
SCALES
MODEL 5 0 10 20 FT
PROTOTYPE 500 0 1000 2000 FT
N
EL+17
EL+18
EL+20
EL+16
EL-50
EL-65
EL-85
EL-75
EL-45
EL-65
-40
RESERVATION POINT
21
22
23
24
25
26
27
28
29
30
31
32